ELECTRICAL ENGINEERING

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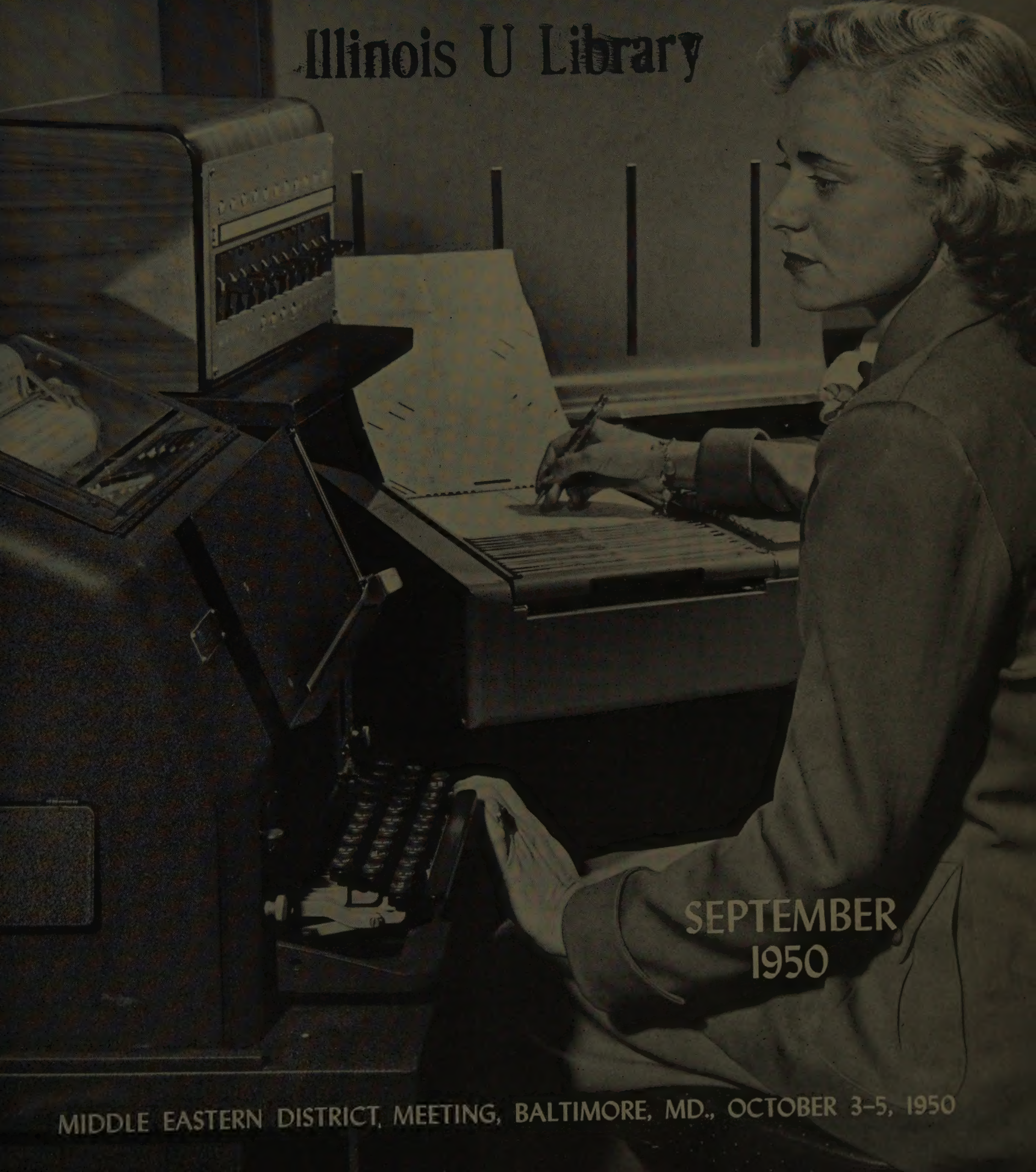

SEPTEMBER
1950

MIDDLE EASTERN DISTRICT MEETING, BALTIMORE, MD., OCTOBER 3–5, 1950

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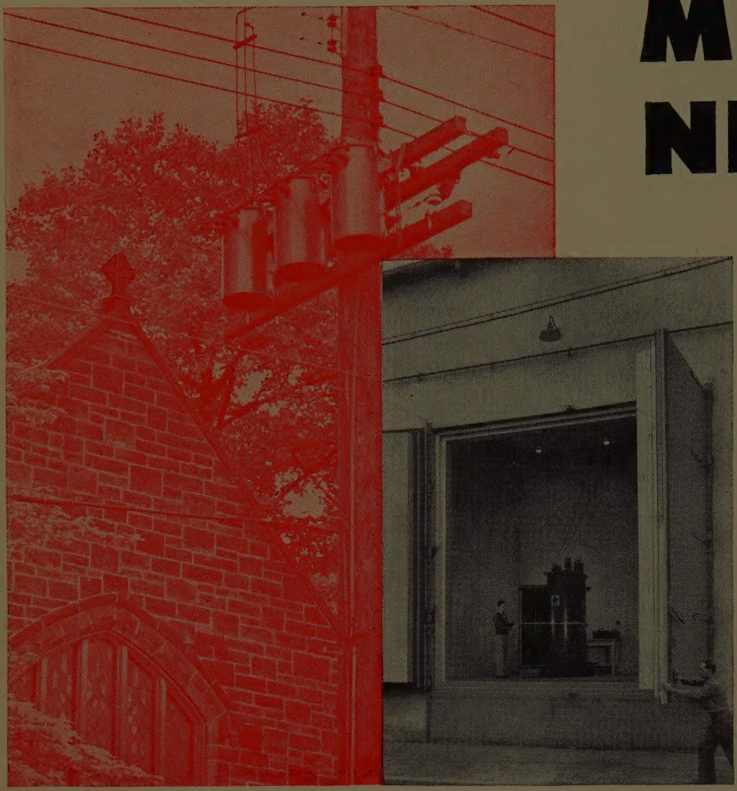

Preparing for audible sound level test on a 1000 kva power transformer at Allis-Chalmers Pittsburgh Works sound laboratory.

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In their efforts to develop better, quieter distribution transformers, A-C engineers are working on complex problems of sound level, surge protection and construction . . . putting improved performance into every size and type. Research, engineering and production team up to give you the best in electrical design and construction.

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Bulletin 61B7309A — ACP (Allis-Chalmers self-protected) distribution transformers to 100 kva.

Bulletin 01B6186B — General description of complete A-C power and distribution transformer line.

Bulletin 61B5726A — Rural transformers, including economical "RU" line, and ACP premium protected.

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SEPTEMBER
1950

The Cover: An operator of the Intelex Ticket Reserving System receiving a message on the teletypewriter in the foreground, and assigning the proper ticket reservation on the automatic card diagram tray in front of her.

Pennsylvania Railroad photo

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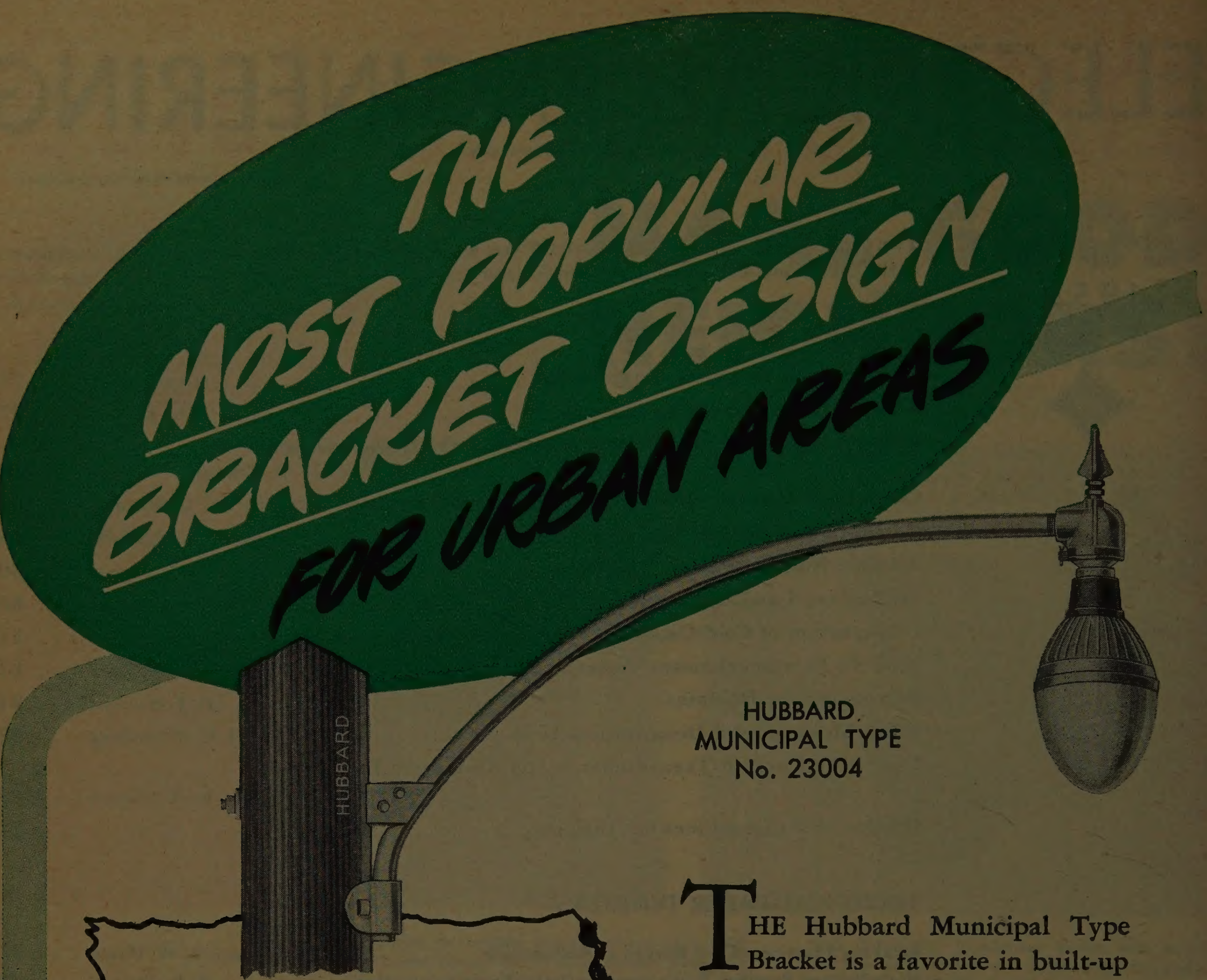

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HIGHLIGHTS........

Officers and Committees List. The complete list of the officers and the main AIEE committees, both general and technical, for 1950–51 appears in this issue (*pages 833–41*). The scopes of the technical committees for the most part remain unchanged; these were described in *Electrical Engineering*, September 1949, pages 808–11.

Dielectrics in Electrical Engineering. The properties of dielectrics which affect their behavior in electric circuits are discussed this month by Dr. A. von Hippel of the Massachusetts Institute of Technology Laboratory for Insulation Research. Methods of changing the properties of materials to tailor them to fit desired properties of a needed component are described (*pages 771–3*).

Electric Ticket-Reserving System. A newly introduced system for making ticket reservations, known as Intelex, is being installed by The Pennsylvania Railroad Company to provide a greatly increased efficiency. It not only speeds handling of reservations, but automatically provides for printed records of all transactions and reduces manual operations to a minimum (*pages 775–80*).

Conversion Unit for Projecting 3- by 4-Foot Television Pictures. A 3- by 4-foot television picture is obtained by projection from a small size table-model television receiver by use of the Norelco Protelgram projection system (*pages 788–91*).

Perception of Electric Currents. Tests made at the University of California show that the current required for perception is almost proportional to the frequency between 1,000 and 100,000 cycles. Direct current produces a sensation of warmth; alternating current below 10,000 cycles produces a tingling or prickling sensation which becomes less intense as the frequency increases, until the sensation becomes one of internal warmth between 100,000 and 200,000 cycles (*pages 794–800*).

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Rubber Insulation Failures. Soil microorganisms as a cause of the failure of rubber insulation is investigated in this issue. Accelerated tests have been made under conditions conducive to the growth of microbes, and the tests show the effect that the presence of these organisms have on rubber and synthetic insulations. Ways of avoiding the action of soil microorganisms on insulation have been tested and are described as well (*pages 782–7*).

Counting or Stepping Tubes. Counting at extremely high speeds is done by the use of series of multivibrators or glow discharge tubes. This month is described a new type of cold cathode in which one cathode is coupled to the next within one common tube envelope. Illustrative performance data are given for a typical tube (*pages 810–13*).

Audible Noise of Power Transformers. More and more are low-noise-level transformers being required for installations in crowded areas. To achieve a reduction in noise level without making costs prohibitive, manufacturers of power transformers are using new designs which make use of new materials, processes, and material applications (*pages 800–05*).

Microwave Gas Discharges. M. A. Biondi of the Westinghouse Research Laboratories describes the results obtained from tests made on microwave gas discharges. He describes the mechanism of ionization of a gas by a microwave field and compares it to d-c discharge ionization processes. He discusses the studies which were made and suggests applications to which the microwave discharges may be put (*pages 806–09*).

Modern Servomechanism Testers. An ordinary oscilloscope may be used as an error detector for measurement of servomechanism attenuation and phase shift if packaged sources of sinusoidal input and reference signals of variable frequency are used (*pages 814–16*).

Ferromagnetic Domains. The difference between paramagnetism and ferromagnetism can be explained by postulating the existence of domains in strongly magnetic materials. In a sample of unmagnetized iron, the domains are already highly magnetized, but they point in various directions. Application of an external field serves to align the domains in the same direction, causing the sample to appear highly magnetized. In this article, the author outlines the historical development of domain theory and shows photomicrographs of typical domain structures (*pages 817–22*).

AIEE Proceedings

Order forms for current AIEE *Proceedings* have been published in *Electrical Engineering* as listed below. Each section of AIEE *Proceedings* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *Transactions.*

AIEE *Proceedings* are an interim membership service, issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 567–8; Jan '47, pp 82–3*). They are available to AIEE Student members, Associates, Members, and Fellows only.

All technical papers issued as AIEE *Proceedings* will appear in *Electrical Engineering* in abbreviated form.

Location of Order Forms	Meetings Covered
Jul '49, p 47A	South West District Summer General
Nov '49, p 51A	Pacific General Fall General
Feb '50, p 46A	Winter General
Jul '50, p 30A	Winter General North Eastern District Great Lakes District Summer and Pacific General (1950)

Pulse Equipment for Measuring Deionization Time. Methods of determining deionization time which use square waves yield more accurate results than those methods which use exponential or sinusoidal waveforms. This article describes this pulse equipment (*pages 823–7*).

Use of the Current Transductor. The current transductor is a device with many of the characteristics of the a-c transformer and is a practical piece of apparatus for metering direct currents. However, it provides insulation between the d-c circuit and the metering circuit, and can be used for the measurement of very high quantities of direct current without the fire hazard inherent in d-c shunts which are usually used to measure direct current. The current transductor is a new device that should find a permanent place in the field of instrumentation (*pages 828–32*).

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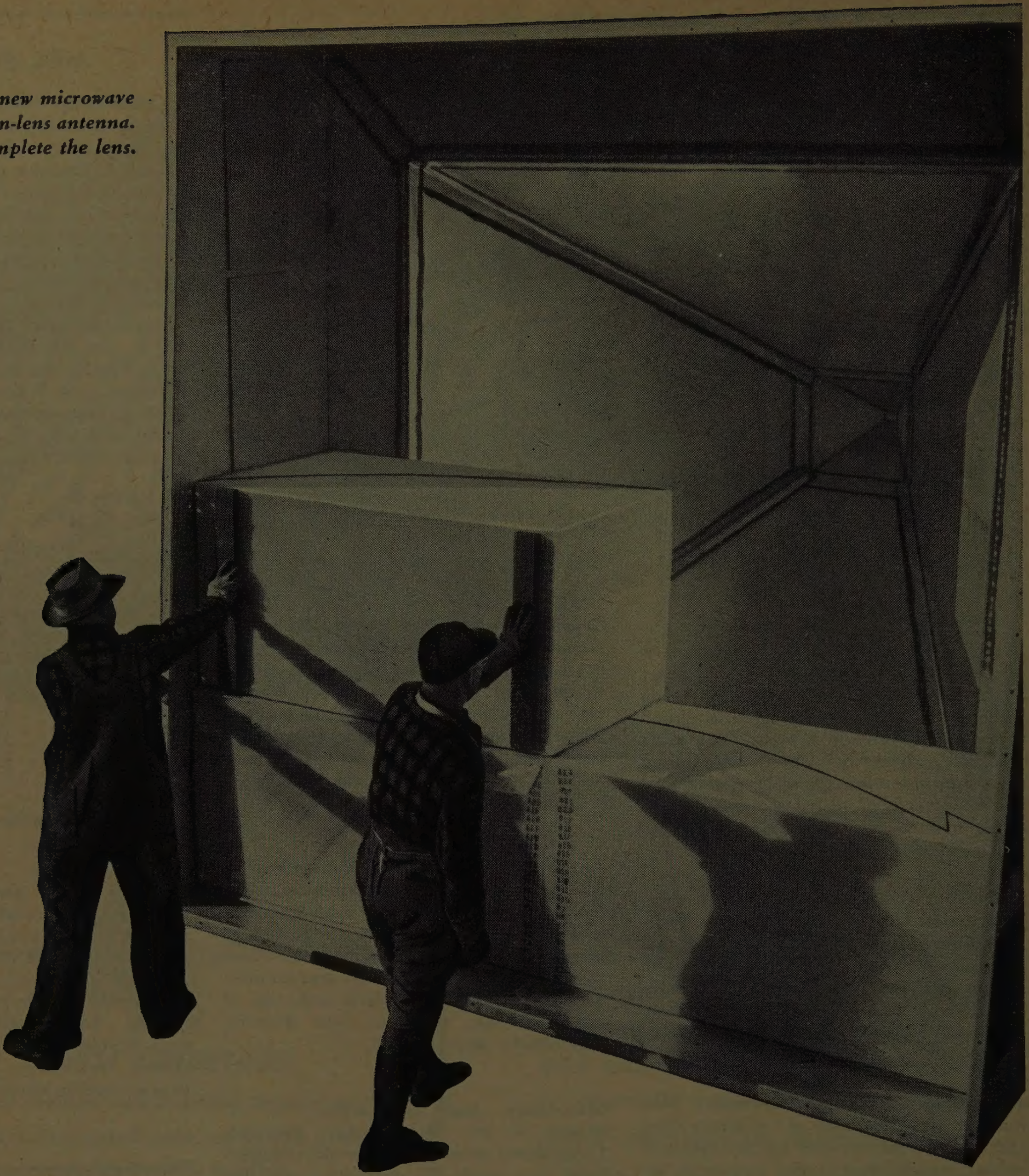


Mounting Bell's new microwave lens in a horn-lens antenna. Other blocks will complete the lens.

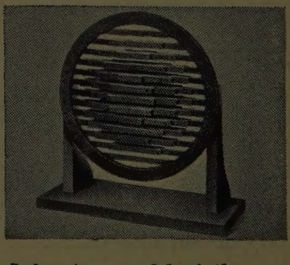
A focus on better, low-cost telephone service

In the new microwave radio relay system between New York and Chicago, giant lenses shape and aim the wave energy as a searchlight aims a light beam.

Reasoning from the action of molecules in a glass lens which focuses light waves, Bell Laboratories scientists focus a broad band of microwaves by means of an array of metal strips. To support the strips these scientists embedded them in foam plastic which is virtually transparent to microwaves. Rigid and light in weight, the plastic is easily mounted on relay towers.

This unique lens receives waves from a wave guide at the back of the horn. As they pass across the strips, the waves are bent inward, or focused to form a beam like a spotlight. A similar antenna at the next relay station receives the waves and directs them into a wave guide for transmission to amplifiers.

This new lens will help to carry still more television and telephone service over longer distances by microwaves. It's another example of the Bell Telephone Laboratories research which makes your telephone service grow bigger in value while the cost stays low.



Laboratory model of the new lens. A similar arrangement of metal strips is concealed in the foam plastic blocks in the large picture.

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Dielectrics in Electrical Engineering

A. von HIPPEL

The first of a series* covering dielectrics, this article shows a way of modern thinking about the subject. Dielectrics are considered from the viewpoint that they are any material into which electric, magnetic, or electromagnetic fields penetrate during the penetration.

CLASSICAL electrical engineering views matter from the standpoint of Maxwell's theory as a means of storing electric and magnetic energy and of dissipating such energy by conduction and other irreversible processes. It considers, for any given material, these properties of storage and dissipation as fixed quantities which may be tabulated under the headings: permittivity (dielectric constant), permeability, and conductivity. After obtaining such tables and setting aside a special corner for dielectrics, defined as nonconductors of electricity,[1] the engineer dismisses the subject of materials and returns into his private world of field vectors and equivalent circuits.

However, his seclusion has become an uneasy one because the facts do not fit this simplified picture. This became apparent already in the 18th century when two professors stretched a student between the terminals of an electrostatic machine and tried to determine whether he was an insulator or a conductor (Figure 1).[2] The issue is still with us. Careful scrutiny of other dielectrics during the past 30 years proved that this is not an exceptional situation, but that any material may show conduction to a varying degree depending on the conditions and the pretreatment chosen. The American Standards Association definition that a material is an insulator if "the flow of current through it can usually be neglected"[3] is of very little help in this situation. In place of a rigorous classification we need a new insight into the properties of materials and the role they should play in the electrical engineering of tomorrow.

The relatively inefficient use of materials in electrical engineering today stems from the still-prevailing idea that dielectrics have unalterable properties and are bestowed on us by nature (such as oil, mica, and shellac) or by industry as the accidental by-products of a manufacture directed towards other goals (such as plastics, paper, and ceramics). These premises have to be revised. The properties of materials can be changed within wide limits, and our goal should be to tailor them to order by combining the proper atoms and molecules in the fitting patterns.

Proceeding in this direction we have to search for a molecular interpretation of the terms permittivity, permeability, and conductivity. Then it becomes apparent that behind the macroscopic factors are hidden a variety of molecular phenomena which may be amenable to control, and that the atomistic events leading to energy storage and dissipation are so intimately interwoven that a new and much broader definition of the term dielectrics is in order. Instead of identifying the name with a class of so-called insulators it may be applied to all nonmetals when they are contemplated from the specific standpoint of their interaction with electric, magnetic, and electromagnetic fields. Any material into which such fields penetrate is, at that time, a dielectric.

At first sight this definition may appear so all-inclusive as to be practically useless; it includes even metals as a boundary case. But it is just this freedom of ranging from gases to liquids to solids and from insulators to semiconductors to metals which allows us to acquire the basic knowledge for a synthesis of materials with prescribed electric and magnetic properties.

If, for example, a solid of high electric strength is desired, the breakdown phenomenon in gases may give the first clues. The electrical landscape of Figure 2, a discharge in nitrogen produced by a fast transient, shows in succes-

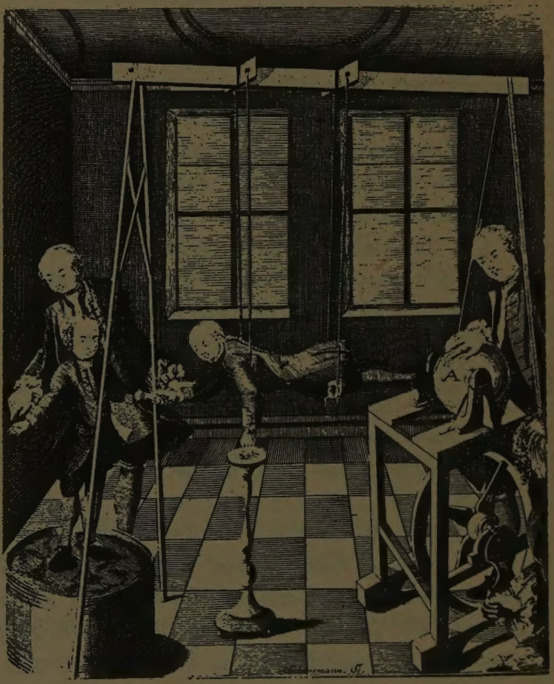

Figure 1. An 18th century experiment to determine whether the student was an insulator or a conductor

---

* First in a series of five papers from the Symposium on Dielectrics, held during the AIEE Winter General Meeting, January 30–February 3, 1950, New York, N. Y. The symposium was under the joint sponsorship of the AIEE and the American Physical Society.

A. von Hippel is Professor of Electrophysics and Director of the Laboratory for Insulation Research, Massachusetts Institute of Technology, Cambridge, Mass.

sion[4] how electrons multiply in avalanche fashion and, migrating outwards, leave positive space charge sectors behind; how, next, certain spots on the cathode begin to erupt and emit electrons so profusely that a negative spark drills into space; and how, finally, the descent of the transient voltage saves the situation, and a positive spark removes the negative space-charge cloud. Armed with this information on the origin of electrons, on impact ionization, space-charge formation, and means of rendering electrons harmless by slow-down and trapping, we can turn to liquids and solids and see how these concepts have to be altered and amended to explain the breakdown in the condensed phases and to bring it under control.[5,6]

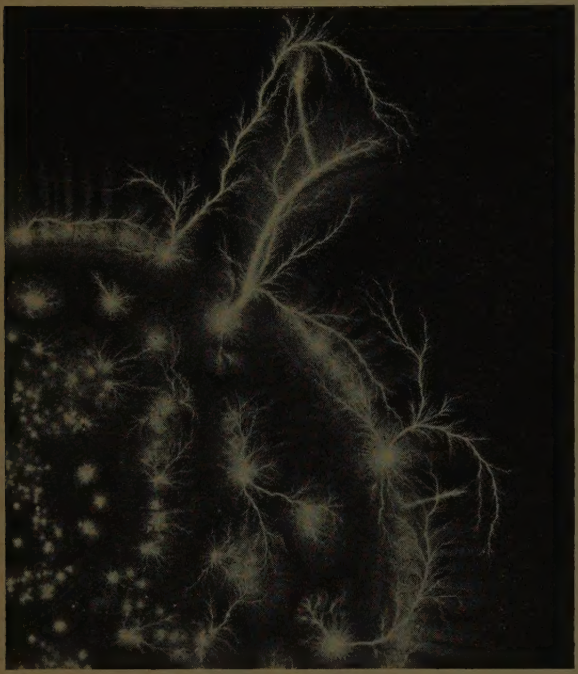

Figure 2. Transient discharge in nitrogen showing how the electrons multiply as in an avalanche

Similarly, if a maximum of electric energy is to be stored in a minimum of space, we will first have to investigate how the permittivity of gases is produced by electric dipoles. On the basis of this knowledge we are learning today how such dipoles can be forced in solids to align themselves in parallel arrays to form materials of extremely high dielectric constant. Such substances as barium titanate,[7] called ferroelectrics in analogy to the ferromagnetics where magnetic dipoles orient spontaneously, show many surprising properties like the domain pattern of Figure 3,[8,9] which are now being clarified by further studies.

Much has still to be learned about the processes of polarization, magnetization, and conduction, and the electrical engineer may therefore feel tempted to sit back and wait until the physicists and chemists have unraveled these mysteries of nature. This, I believe, would be a mistake, because no profession can rely on others to solve its own problems without losing control over its destiny. Either we train a new kind of electrical engineer who can think in terms of dielectrics as well as field and circuit concepts, or we exclude him from a creative participation in a field of molecular engineering which should be the second half of his profession.

What, then, are the macroscopic parameters of dielectrics for which we seek a molecular interpretation? Let us first consider a capacitor connected to a sinusoidal voltage source V (Figure 4). When empty, it shows a geometrical capacitance C_0 and is traversed by a charging current

$$I_c = j\omega C_0 V$$

advanced by 90 degrees in temporal phase against the voltage. Filled with a dielectric, its capacitance increases to

$$C = C_0 \frac{\epsilon'}{\epsilon_0}$$

where ϵ' and ϵ_0 designate the permittivities of the material and of vacuum respectively. Simultaneously, a loss-current component

$$I_l = GV$$

in phase with the voltage appears; thus the power-factor angle of the total current I against the voltage V is reduced to a value below 90 degrees.

It would be premature to conclude from this observation that the dielectric is equivalent to a simple resistance-capacitance circuit (Figure 5). Its frequency response may be quite different and the conductance G not at all due to a migration of charge carriers but to some other energy-consuming process. Thus it has become customary to express noncomittally the simultaneous existence of loss and charging current by the introduction of a complex permittivity

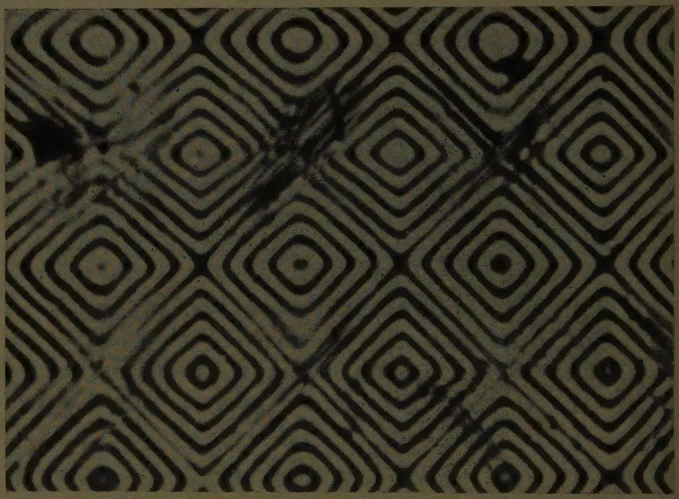

Figure 3. Domain pattern in barium titanate

$$\epsilon^* = \epsilon' - j\epsilon''$$

and to write the total current as

$$I = I_c + I_l = j\omega \frac{C_0}{\epsilon_0} \epsilon^* V = \frac{C_0}{\epsilon_0} V\{j\omega\epsilon' + \omega\epsilon''\}$$

The parameter ϵ'' is the loss factor of the dielectric; the product

$$\epsilon''\omega=\sigma$$

defines the dielectric conductivity of the material (which may be a true conductivity or not), and the ratio of loss current to charging current

$$\tan\delta=\frac{\epsilon''}{\epsilon'}$$

is known as the loss tangent of the dielectric or its inverse as its quality factor

$$Q=\frac{1}{\tan\delta}=2\pi\frac{\text{energy stored per half cycle}}{\text{energy dissipated per half cycle}}$$

If the material is transferred from the capacitor of Figure 4 to a coil of the geometrical inductance L_0, a magnetization current

$$I_m=\frac{V}{j\omega L_0\dfrac{\mu'}{\mu_0}}$$

may be observed which lags behind the voltage by 90 degrees (Figure 6). The factors μ' and μ_0 designate the permeabilities of the dielectric and of vacuum respectively. If the medium dissipates some energy in heat during the magnetization cycle, in addition again a loss current in phase with the voltage appears and the magnetization in the magnetic field, in complete analogy to the polarization in the electric field, may be described by a complex permeability

$$\mu^*=\mu'-j\mu''$$

Thus, the electric and the magnetic response of a dielectric to sinusoidal fields is determined by the two complex parameters ϵ^* and μ^*. As a third macroscopic parameter the electric breakdown strength of materials enters.

This series of articles is limited in essence to the complex permittivity from the molecular standpoint. The magnetic effects, save in ferromagnetics, are of a much smaller order of magnitude than the electric ones and of no immediate concern to the engineer. Electric breakdown in liquids and solids is not included because our knowledge in that field is rapidly expanding at present and a more informative representation should be possible at a somewhat later date. As it is, the subject of storage and dissipation of electric energy represents by itself a large segment of our present-day knowledge of electrons, atoms, and molecules and their concerted action in liquids and solids.

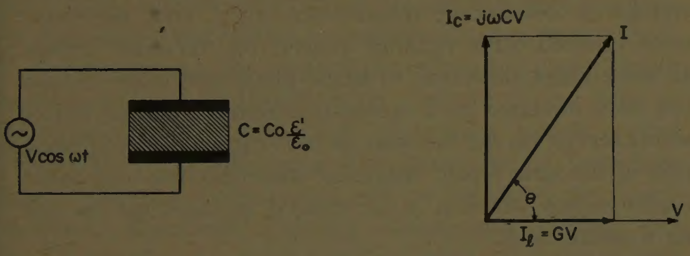

Figure 4. Dielectric-filled capacitor connected to a sinusoidal voltage source with vector diagram to show phase angle of current with respect to voltage

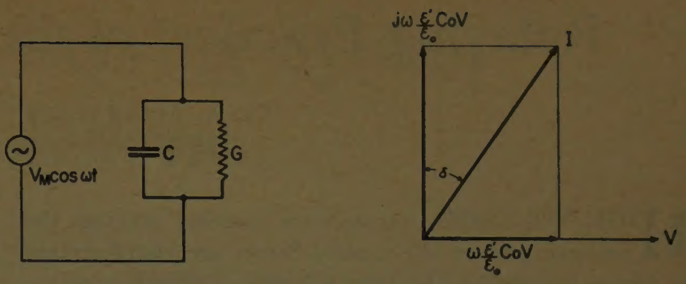

Figure 5. A dielectric in an electric field is normally not equivalent to a simple resistance-capacitance circuit (left), but may be represented noncommittally by a complex permittivity $\epsilon^*=\epsilon^*(\omega, T)=\epsilon'-j\epsilon''$ (right)

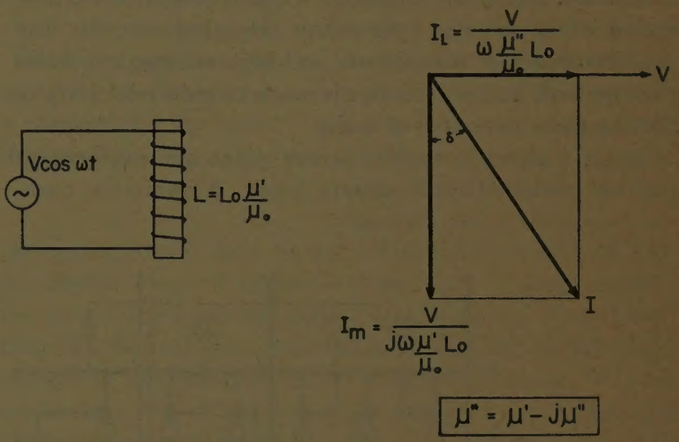

Figure 6. Dielectric-filled coil connected to sinusoidal voltage source with the vector diagram showing the phase angle of the current and voltage

The articles which will follow in this series may be divided into two groups. The first will be concerned with phenoma due to dipoles and bound charges, while the latter will emphasize the action of moving charge carriers. Each group of articles will advance from atoms and molecules in the gaseous state, where our knowledge is relatively far advanced and ends with problems of the solid state which are, at present, the most mystifying.

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Relaying Practices of the Bureau of Reclamation

W. A. MORGAN
MEMBER AIEE

R. W. WORLD
ASSOCIATE AIEE

HIGH-VOLTAGE transmission systems serving the western part of the United States are characterized by longer line sections between substations than is common in the East where population density is greater. Relaying of power systems of the Bureau of Reclamation, United States Department of the Interior, presents, therefore, somewhat different problems than usual.

One objective in Bureau power system designs is the obtaining of maximum amount of power system for the least expenditure. While several economical measures have been adopted, especially at numerous low-capacity substations, this is accomplished without jeopardizing protection of equipment. At many receiving stations, the rare occurrence of transformer and high-voltage bus faults is recognized, and no attempt is made to gain selectivity in clearing these two types of faults.

Figure 1 shows a typical power plant arrangement as might be designed at the present time. A minimum number of circuit breakers is used in the interest of economy; current transformer circuits are not transferred when the spare circuit breaker is used, and a line position in the switchyard is eliminated by putting the spare circuit breaker in the transfer-bus position of a transformer circuit. Arrangement of power plant or receiving station switchyards varies with size and importance of loads or generator units.

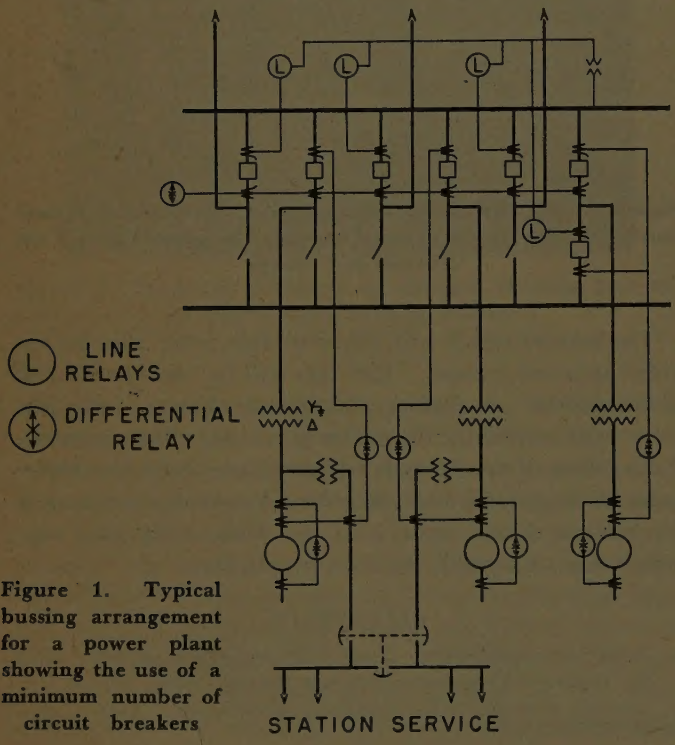

Figure 1. Typical bussing arrangement for a power plant showing the use of a minimum number of circuit breakers

High-voltage main busses are given differential protection with induction-disk overcurrent relays having short time characteristics. Generator and transformer standard-speed induction-type ratio differential relay zones overlap, as do transformer and high-voltage bus zones. At many receiving stations, transformer differential relays trip all circuit breakers for either transformer or bus faults.

Three-zone distance relays of either the standard or special long-lines type, as required, are used for protection against multiphase faults on nearly all transmission lines. Carrier-current pilot relaying with terminal circuit breakers arranged for reclosing in 20 cycles is usually applied to all transmission lines rated 115 kv or greater. Ground-fault protection is obtained by induction-disk relays operating from residual line currents, usually polarized by transformer neutral current where the directional feature is required. Current-phase-comparison carrier relaying may be applied in only a few locations because of the low fault-current characteristic of the Bureau's systems. It is considered essential to provide protection for all types of faults, including 3-phase faults at ends of long lines.

Tapping of 115-kv transmission lines is sometimes the only economically feasible method of serving loads at intermediate points between major switching stations. This practice of tapping loads to lines brings with it usual problems well known to relay engineers. Where the line may be energized from the load, undervoltage relays energized from line potential are provided to assure that the line is de-energized before reclosing. In some cases, reverse power and under-frequency relays are provided at load substations to prevent load generators from attempting to charge or supply other loads on the high-voltage line. In addition, tapping presents a special problem where 20-cycle reclosing is to be applied to terminal circuit breakers.

At some substations which tap the line, calculations have shown that fuses would be slower than primary transmission line distance and ground relays in clearing either high-voltage or low-voltage transformer faults, and fuses have been omitted with reliance placed on terminal relays. In some cases, objection to single-phase operation of fuses has been obviated by a spring-operated grounding switch where service on the line may be interrupted, or by application of the new 3-pole operating disconnecting-type interrupter switch where it is not desired to interrupt the line for a station fault.

The Bureau's practice has been to install capacitor potential devices for relaying instead of potential transformers wherever there is a saving in initial cost. The Bureau has had no direct experience of false relaying caused by transients introduced by capacitor potential devices.

Digest of paper **50-140**, "Relaying Practices and Economical Switching Station Arrangements of the Bureau of Reclamation," recommended by the AIEE Committee on Relays and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Electric Ticket-Reserving System

W. R. TRIEM J. S. JAMMER

A new system for reserving space in trains is being installed at the Pennsylvania Station in New York. This system, which is almost entirely electric, is designed to speed up the answering of customers' questions and the making of reservations by reducing manual operations to a minimum. Many errors should be eliminated because all information is transmitted by teleprinter instead of orally.

STEADILY increasing difficulties have marked the expansion of the reservation systems of railroads and air lines over the past two decades. This may in large part be due to the greater number of people traveling today, to the increased speed of the vehicles, and perhaps also to the efforts that the carriers have made in supplying a large variety of accommodations. A large railroad can provide 12 different types of space such as berths, club chairs, roomettes, and so forth, all of which must be recorded in the reservation department to assure that every available seat is sold and at the same time to prevent duplicate selling that would irritate to the passenger and endanger good public relations.

When it is realized that almost all of the many different types of accommodations can be had in a single train, and that for a number of weeks previous to the departure time the traveling public will be making reservations, buying tickets, cancelling reservations, and inquiring about available space, some idea of the complexity of the reservation records becomes apparent. The number of reservation transactions required to fill the cars of a typical train may approach 300.

The Pennsylania Railroad over the years has maintained a manual reservation procedure at Pennsylvania Station in New York City and at six other major terminals. Clerks in the New York Bureau, for example, seated around movable files containing some 25,000 car diagrams, must manually select that particular diagram for the destination, day, train, and car for which an inquiry has been received, or on which a reservation or cancellation is to be recorded.

During the past few months, the railroad has been testing and installing at Pennsylvania Station a new type of electromechanical automatic reservation system called "Intelex,"[1]* a development of the International Telephone and Telegraph Corporation and its associate, the International Standard Trading Corporation. When the installation has been expanded to cover all trains leaving New York Terminal, it is estimated that a reduction of over 50 per cent will be effected in the time required to cover a transaction relating to a reservation. Eventual expansion is planned by the railroad to cover all reservation handling over the entire system.

Before describing the Intelex system, it may be in order to give a brief description of the manual reservation procedure now used by the railroad.

MANUAL RESERVATION HANDLING

THE BASIS of reservation recording for railroads is the car diagram, a card of heavy paper about $3^1/_2$ inches wide by 12 inches long. On this card, in approximately the same position as on the actual railroad car, are marked spaces in which are entered the reservation information pertaining to each particular roomette or berth. Thousands of these cards are stored in movable files. An illustration of two of the types of files in current use is given at the right in Figure 1. In each of the files are stored the car diagrams for one section of the system for 60 days ahead. For instance, one of the top files in Figure 1 might be New York–Chicago trains; the next, New York–St. Louis, and so forth. Calls from ticket clerks and other railroad personnel are handled by automatic telephone switching through a private branch exchange, while calls from outside customers pass through clerks at a manual board.

A customer at a ticket window informs the ticket clerk of the date, train, and type of accommodation desired. The clerk then dials the proper telephone number and when one of the space-distributor clerks handling the file for that particular train is free, he will be answered. The ticket clerk then passes on the information, and the distributor picks out the proper set of diagrams from among those in the file. Searching through the diagrams for this train, the distributor attempts to find a vacant space of the type requested. If successful, the ticket clerk is informed of the car and space numbers, which he enters on the customer's ticket; and in turn, the ticket clerk informs the distributor of the ticket number, which is duly entered on the car diagram. The customer then pays for the ticket and departs.

Should the customer have telephoned from his home or elsewhere, the method of handling is much the same. Instead of entering a ticket number on the car diagram, however, the customer's name is entered together with the time limit within which he must pick up his ticket at one of the ticket-selling points of the railroad. When the customer arrives at a ticket window, he informs the clerk of his name and the date, train, car, and space that was reserved for him. The ticket clerk then calls the distributor clerk and checks by having the clerk find the original transaction. If the

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* The term "Intelex" is a registered trade mark.

W. R. Triem is general superintendent of telegraph of The Pennsylvania Railroad Company, Philadelphia, Pa., and **J. S. Jammer** is a vice-president of the International Standard Trading Corporation, New York, N. Y., which is an associate of the International Telephone and Telegraph Corporation.

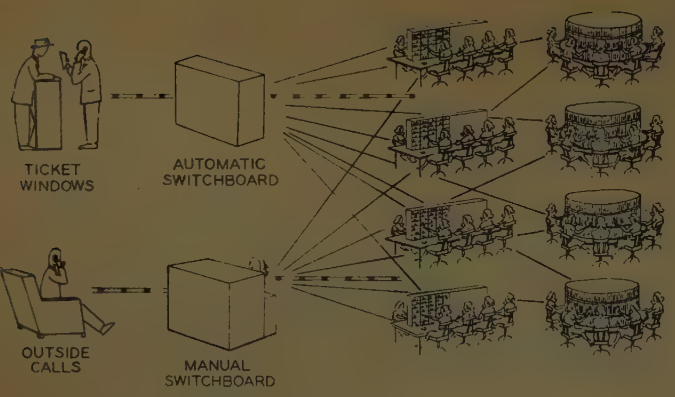


Figure 1. Manual reservations network in which customers and ticket clerks communicate by telephone with the distributor clerks at the files

information is correct, the ticket is sold and the distributor erases the customer's name and writes in the ticket number.

Should this customer decide to cancel his trip, he informs one of the railroad's agents of the day, train, car, and space number. This is passed along to the distributor and the previously entered information is erased from the car diagram.

About half an hour before train time, the diagrams relating to the train are removed from the file, microfilmed for record purposes, and passed along to the conductor of the train so that he may check the travelers' tickets. An attempt is made at this time to sell any empty space on the train. As the trains depart, the spaces from which the diagrams were removed from the file are filled with a fresh set for the same train on the same section for a date 60 days ahead.

This, briefly, is the manner in which the present-day systems operate. In the busiest season at Pennsylvania Station as many as 30,000 transactions a day have been handled by the 215 reservation people in the bureau. For the summer schedule, 79 trains comprising 427 cars leave the station daily, traveling to some 80 destinations with as many as 12 types of space—a total of 6,480 individual accommodations in 1,250 groupings of space and destination. This does not take into account such additional complications as are raised when extra cars are added to a train, or car substitutions are made.

In analyzing the manual method of handling reservations, it has been found that one of the main difficulties is the introduction of errors through misunderstanding of oral instructions, transposition of dates and numbers, and similar human factors.

Note that the only written records exchanged are the customer's car and space number that was written on his ticket by the ticket clerk and the ticket number written on the car diagram. Also, this information was exchanged orally.

On popular trains and on heavily traveled sections of the railroad, one distributor clerk may have to wait until another clerk finishes with the cards for a particular day and train before she can answer a request.

Again, as a particular train is approaching the date and time of departure, more and more requests for space on that train will be received. The distributor clerk must remove the appropriate diagrams from the file each time one of these calls is received, even though it is probable that no space is available.

GENERAL DESCRIPTION OF INTELEX

In the development of the Intelex system, elimination of all possible oral communication has been stressed. It may be noted by reference to Figure 2 that all communication, with the exception of calls from outside customers, is by means of teleprinters. This, in addition to minimizing the errors previously mentioned, has the advantage that printed records of all transactions are provided automatically.

The Intelex system may be divided into three interrelated parts: an availability service, a reservation service, and a ticket-information delivery service. In Figure 2, there is on each ticket clerk's desk an inquiry set, consisting of a telephone-type dial and a telephone receiver or loud-speaker. By dialing a code number, the clerk is connected through an automatic switchboard with one of a group of magnetic recorders. On each recorder, an announcer has placed up-to-the-minute information on the available space on trains departing for a single city on a certain day.

For the purpose of illustration, assume that a customer telephones the bureau to make a reservation. He will be connected with one of the telephone sales operators, who will use the inquiry service in finding suitable space. If the clerk finds accommodations that are satisfactory to the customer, he obtains the customer's name and the city ticket office at which he wishes to pick up the ticket. The clerk then turns to a teleprinter at his desk and types out a message of the following form.

1824 6/25 29 AR NY-CHI 1604D3 CTA 6/17 JONES R.

The first four digits of this series are a code in which **18** indicates that a New York-Chicago train is desired and the **24** indicates the date; second week from the current week, fourth day (Wednesday). This is the same code that the clerk uses for the inquiry service. The **6/25** is the date in uncoded form, a double check. The digits **29** indicate the train number (*Broadway Limited*), and the **AR** means one roomette (**A** = one, **R** = roomette). **NY-CHI** are the terminal stations for the trip, and **1604D3** is a composite serial number for the transaction in which **16** is the current day of the month, and **O4D3** is the fourth transaction of clerk number **D3** on that date. The **CTA 6/17 JONES R.** indicates that customer R. Jones has said he will pick up his ticket at city ticket office **A** by June 17.

As indicated in Figure 2, this message is transmitted through automatic switching equipment to a teleprinter beside one of the distributor clerks in front of the file cabinets. The first series in the preceding message **1824** enables the switching equipment to select cabinet 18. Each cabinet contains the car diagrams for all trains between two terminal points on the railroad system for 60 days in advance. At the same time as this message is being relayed on the teleprinter beside the distributor, the drawer corresponding to the second week, fourth day automatically slides out in front of the operator.

She then finds in this drawer the series of diagrams corresponding to train 29 and assigns a roomette to customer Jones, noting the serial number **1604D3** on the diagram. To validate this transaction, she will add to the end of the teleprinter message the code **R9 W10**, which means that Mr. Jones has been given roomette number 9 in car W10.

The complete message in this augmented form is then automatically transmitted back to the ticket clerk making the sale, whereupon Mr. Jones may hang up his telephone. At the same time as the distributor clerk retransmitted the message to the ticket clerk, the same message was sent to city ticket office **A**, where Mr. Jones need only give his name to permit the clerk to find all the information required to complete the sale of the ticket without further reference to the reservation bureau.

If Mr. Jones had appeared at a ticket window, the procedure would be the same as that just described, except that the name of the customer is not recorded since the ticket is delivered forthwith.

Had this sale been the last roomette available on the *Broadway Limited* for June 25, the distributor clerk would also arrange to have this information automatically transmitted to the announcer at the availability service. This message is a signal that the recording for that train requires revision. A new recording is made immediately, the previous one being erased automatically, so that the availability information is always kept up to date.

This Intelex reservation system, in addition to its elimination of human errors and the automatic provision of printed records in the station and at city ticket offices, has the advantage of speed. It is estimated that the time required for the machine handling of a reservation or cancellation will not exceed 30 seconds.

The operation of the entire system now having been described, some of the more interesting circuit features may be discussed.

AVAILABILITY SERVICE

THE announcer for the availability service sits in front of a telephone-type switchboard on which are lamp and jack panels. A microphone is placed in front of her (Figure 3). When she receives information over her teleprinter that one of the recordings must be revised, she selects the magnetic recorder for that train by plugging into the proper jack on the panel in front of her. She then proceeds to record a completely new announcement to replace the previous information, which has been erased automatically. In the meantime, should any of the ticket clerks happen to dial for that record, they will hear instead a special recording saying that a new record is being made and will be available in a few seconds. When she disconnects, the new recording is available immediately.

These recorders (Figure 4) are of the magnetic type in which the recording material is on the surface of a cylinder. Maximum recording time is $1^{1}/_{2}$ minutes, which is ample for the longest record. The recording and playback head is mounted on a carriage that travels across the surface of the cylinder. At the time that the operator plugs in the microphone, a bar magnet moves near the cylinder to erase the previous record. The recording head, as it advances, carries with it a small trip that is fastened at the exact spot that the announcer stops talking. When the record is being played, this stop returns the playing head to the beginning of the record automatically. Thus no time is lost by waiting for the entire $1^{1}/_{2}$-minute period to play through, yet each new listening starts from the beginning. Any number of clerks may be connected simultaneously to the same recorder.

When dialing over his inquiry set, the ticket clerk uses a 4-digit code such as **1824**. In this code, the **18** indicates the section (such as the New York-Chicago section) and the **24** is a code indicating the date. If a standard 4-digit date code as is used in business were applied here, say for example 11/25, the amount of switching equipment that would be required to select the proper recorder would be increased enormously.

A calendar has been devised (Figure 5) in which the dates are divided into weekly periods. Indication of any date up to ten weeks in advance is thus possible by means of a 2-digit code. The inside slide of the calendar carries the dates and is moved up one line each week on midnight

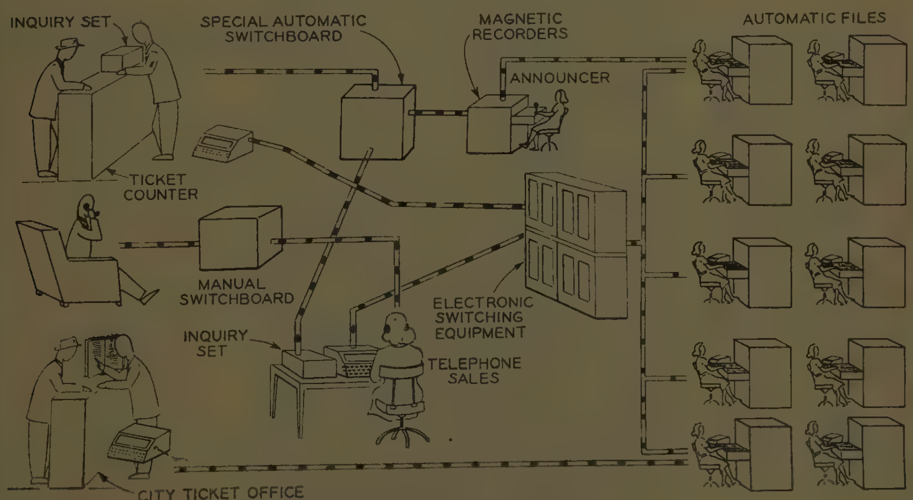


Figure 2. In the Intelex system, all communication is by means of teleprinters. The file cabinets automatically open the proper drawer containing the required diagrams so that the clerk can enter the information on them

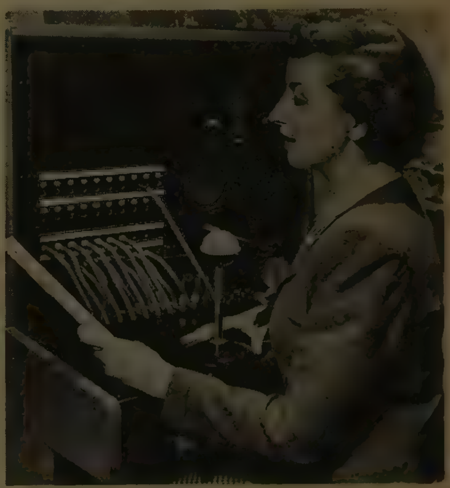


Figure 3. The announcer is making a new availability report which will be used for the inquiry service

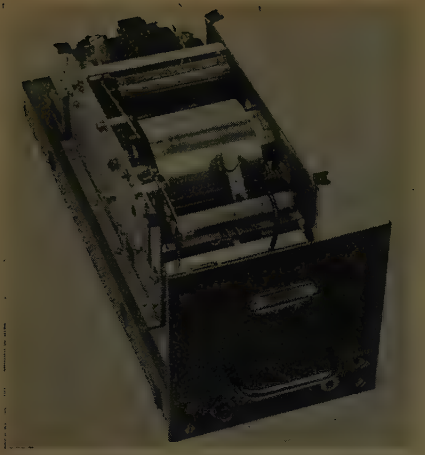


Figure 4. The availability information is recorded on a moving drum of magnetic material. The record is made so that it will repeat as soon as the recorded material is reproduced

Saturday, so that the current week is always number 1. This means that the recorder containing the information for, say, August 17, may be reached this week by dialing 85, but next week, after the clerks move their calendars, they must be able to reach it by dailing 75. Therefore, a time-clock system is included in the switching mechanism to advance the third-digit selector switches by one digit each week.

The recorders each can handle the information for all trains on a single day between two cities. Since reservations are made as far as 60 days in advance, this would mean that 60 recorders are required for each two terminal cities. However, since most of the reservations are made only about one or two weeks in advance, the full capacity of a recorder is needed for each day only for the 14 days preceding train departure. This requires 14 recorders. A full week is handled by each of the next two recorders and the balance of 32 or more days is put on a single recorder. This is a grade-1 rating. This same method of condensing the information is used where only a few trains travel over a lightly loaded route.

Under this system, the sections of the railroad are divided into groups requiring different grades of recorder service, and permit the number of recorders and the amount of switching apparatus to be reduced appreciably. It is estimated that when the installation at Pennsylvania Station, New York, is completed, 240 recorders will be in use.

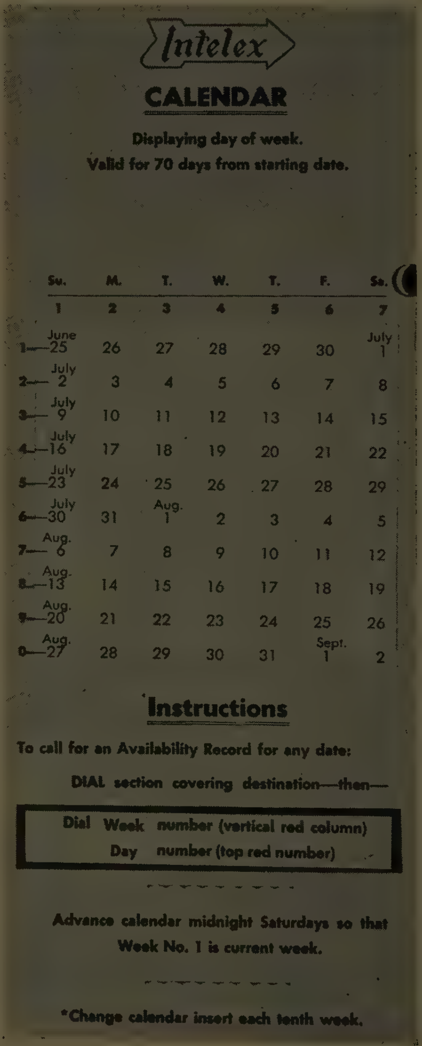
A diagram of the switching system used to route the ticket clerk's call to the proper recorder is given in Figure 6. In this switching circuit, telephone-type relays and step-by-step switches are used. To trace through the circuit, assume that the clerk at the inquiry set has just raised his telephone receiver. Immediately one of the line finders seizes his line. When he begins dialing, the first two digits, indicating the destination of the train, are absorbed by the connector switch. The first digit is used to select the proper destination switch, and the second marks the proper level on the destination switch.

The second two digits, representing the week and day of the requested information, are fed to the calendar translator, in which adjustment must be made for the grade of service (number of recorders) of the particular destination, and the daily and weekly change in the code with respect to the selection of the particular recorder. Since there are four different grades of service, the particular grade into which the destination falls must be taken into account in the translation of the date. The destination, and hence the grade of service, is indicated by the first two digits of the code.

Adjustment for the passage of days and weeks is made in the calendar translator by the clock through the calendar control circuit. Daily adjustment is made at midnight. Therefore, when the second two digits of the code are applied to the calendar translator, the proper contacts on one of the levels of a single destination switch are marked. The destination switch then hunts for these contacts, and the through connection between the clerk's inquiry set and the proper recorder is completed. The recorder then starts, and the availability report is heard.

The clock circuit also controls the record-change indicator control. This circuit, which operates at midnight daily, lights a signal lamp on the announcer's switchboard over each jack that connects to an out-of-date recorder. The announcer then knows that the information on these recorders, which contained the records for the day that has just passed, must be erased and new information recorded for some future day. By tearing off a small paper tag mounted just above the jack on the board, she will see indicated there the particular section and day for which the availability should be placed on the new record.

The calendar-shift marking circuit is installed so that a



Intelex

CALENDAR

Displaying day of week.
Valid for 70 days from starting date.

	Su.	M.	T.	W.	T.	F.	Sa.
	1	2	3	4	5	6	7
1—	June 25	26	27	28	29	30	July 1
2—	July 2	3	4	5	6	7	8
3—	July 9	10	11	12	13	14	15
4—	July 16	17	18	19	20	21	22
5—	July 23	24	25	26	27	28	29
6—	July 30	31	Aug. 1	2	3	4	5
7—	Aug. 6	7	8	9	10	11	12
8—	Aug. 13	14	15	16	17	18	19
9—	Aug. 20	21	22	23	24	25	26
0—	Aug. 27	28	29	30	31	Sept. 1	2

Instructions

To call for an Availability Record for any date:

DIAL section covering destination—then—

Dial Week number (vertical red column)
Day number (top red number)

Advance calendar midnight Saturdays so that
Week No. 1 is current week.

*Change calendar insert each tenth week.

Figure 5. The white part of the calendar carries the dates and is moved up one line each week

ticket clerk who might call after midnight, but before the announcer has revised the record, will be connected to the proper recorder, and not to the recorder holding the information which has already expired.

RESERVATION RECORDING SYSTEM

By means of an electromechanical switching system, the teleprinters of the ticket clerks are connected to the teleprinter and automatic file cabinet of the proper space-distributor clerk (see cover picture). The teleprinter is at the clerk's left. Since she types only 4 to 6 digits and letters in confirming a reservation, it need not be in front of her. In a large file cabinet are 60 drawers in which are filed the diagrams for all trains between New York and Chicago for 60 days from the current day.

By decoding the first four digits of the ticket-clerk's message, the equipment automatically selects and moves the proper drawer in front of the clerk. In this drawer, the diagrams are arranged in groups representing the various trains leaving that day. The diagrams are so designed that when all of a certain type of space has been sold on one train it will be apparent immediately, and the inquiry service announcer may be informed of this change in availability status.

Also visible in the picture, above and to the right of the teleprinter, is a small box mounting a key panel. When the clerk has confirmed a message by addition of the car and space number, she presses a button, which causes the drawer to slide back inside the file cabinet, and the completed message is transmitted to the ticket clerk. By depressing one of the keys on this keyboard, the distributor may also select certain other places to which the message is sent simultaneously. These include the various city ticket offices, the announcer of the inquiry service, and a monitoring supervisor.

Since the code dialed to reach the specific drawer in the proper file cabinet is exactly the same as that used for the inquiry service, it is apparent that the same form of calendar-adjusting device must be used to allow for the changing week numbers. Also, since the 4-digit code number is transmitted in the 5-unit teleprinter code, some form of recoding device must be included.

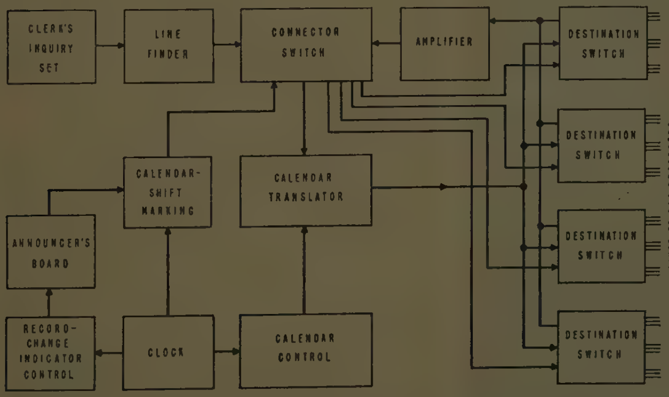


Figure 6. Block diagram of the switching circuit for the availability service

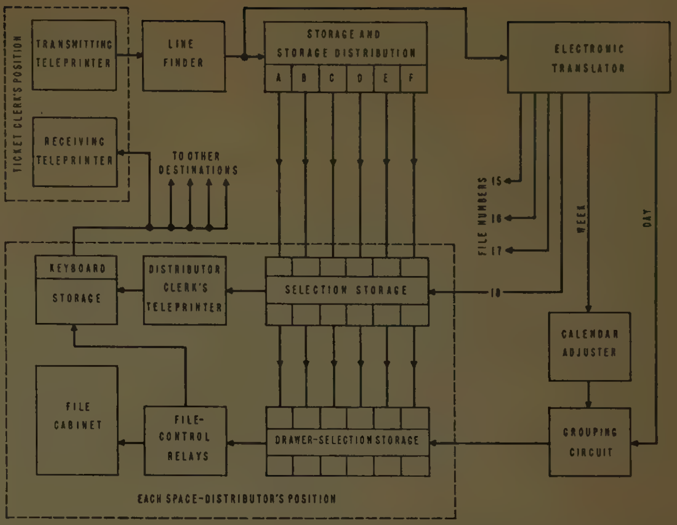


Figure 7. Block diagram of the switching system for the selection of the proper file and drawer at a distributor position. Switching and storage circuits use telephone-type relays and step-by-step apparatus

A block diagram of this switching and storage circuit is given in Figure 7. In the box in the upper left corner are the transmitting and receiving teleprinters in the ticket clerk's office. Separate teleprinters are used for these two functions because more rapid operation is possible. One set of such instruments will take care of the traffic of several ticket clerks. At the start of transmission, connection is made through a line finder to a storage and distribution circuit and also to an electronic translator. In the storage unit the entire message is punched in tape by an instrument combining a typing reperforator with a tape transmitter. Both the reperforator and transmitter in this teleprinter are mounted in the same instrument, and the transmitter is so arranged that the transmitting head will advance along the tape toward the punching head so it can transmit the very last character punched in the tape. Storage space is provided for punched tape in case the transmitting function is held up while messages are still being received.

Then, the entire ticket clerk's message is stored in the tape of one of the teleprinters *A*, *B*, *C*, *D*, *E*, *F* while the first four digits of the message containing the code for the file cabinet corresponding to the section of the railroad and the day of the requested reservation are fed to an electronic translator. This device consists of a group of gas-tube counting chains and storage relays so arranged as to decode the 5-unit teleprinter code and provide the file number, week, and day of the message in usable form.

Since only a weekly change in code number is required, the calendar adjustor is very simple; it consists of a slip-multipled stepping switch moved once a week by a clock. Combination of the week and day information in the grouping circuit provides the information as to which drawer in any cabinet contains the car diagrams for the desired day. There are 60 drawers in each of the cabinets, and they are all similarly arranged as to the day involved.

The electronic translator activates the selection-storage circuit of file cabinet number 18, should that have been the one requested, and the number of the requested drawer is transferred into the drawer-selection storage circuit of this cabinet. It may be mentioned here that in the translation of the teleprinter code, the selection of the desired cabinet, and the storage of the information in the circuits of the cabinet, only about one second is required. Hence, the message capacity of the translator circuit is approximately 3,000 per hour. The equipment may be multipled if greater traffic is expected.

In effect, the storage circuits of cabinet 18 have now been informed that there is a message waiting on say, storage unit E of the storage and storage-distribution circuit and the drawer number pertaining to that message. If there is an unanswered message yet on the distributor clerk's teleprinter, this information will be stored until the preceding message is answered. This permits stacking of messages in each space-distributor position. If there is unanswered traffic at any file, a lamp is lighted above the position to attract attention.

When the distributor clerk's position is free of unanswered traffic, the message on storage unit E is transferred to the distributor's teleprinter and at the same time the file-control relays cause the proper drawer to move out of the cabinet. While the message is being transferred to the distributor's teleprinter, it is also punched in the tape of another storage reperforator-transmitter. When the distributor confirms the reservation or cancellation by typing four digits at the end of the message on her teleprinter, these are also punched in the tape in the storage unit.

After the clerk has completed all action on the message, she will depress one or more keys on the keyboard and will push the start button. Then, the drawer will return into the file and, at the same time, the complete message will be transmitted from the tape of the storage unit to the ticket clerk's receiving teleprinter and also to such other places as may be required.

CONCLUSIONS

The Intelex reservation system will provide a greatly increased efficiency in the handling of reservation traffic. In addition to speed of operation, it provides for the automatic provision of printed records of all transactions and reduces to a practical minimum all manual operations.

It is aimed at separating the process of answering the customer's questions as to what space is available from the process of actually entering the sales on the car diagrams, and accomplishes this without losing the personal touch. Under the manual system, these two processes were inseparable, resulting in clerks' waiting for each other to release diagrams. At times of busy traffic, these conditions tended to snowball, and it is in these busy times that Intelex will show the greatest benefit to both the traveling public and to the railroad personnel.

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1. Intelex—Automatic Reservations, J. D. Mountain, E. M. S. McWhirter. *Electrical Communication* (New York, N. Y.), volume 25, number 3, September 1948, pages 220–31.

Glass-Jar Oven Makes One-Color Mirrors

Mirrors that reflect only a single color are created in this glass-jar oven by color television scientists of the Westinghouse Research Laboratories. Here, K. L. Fromm measures the brightness of the light produced by the "electric fire" in the oven. The cage protects the scientist in case the glass-jar oven should break. By depositing ultrathin layers of metallic compounds on clear glass, mirrors are produced that reflect either red, blue, or green light. The mirrors are used at both the transmitting and receiving ends of the television system. At the transmitting end, the mirrors pick up the color picture from the camera and break it down into its three basic colors—red, blue, and green. These colors are then sent in the proper sequence through the system. At the receiving end, another set of mirrors "gathers" in the colors, regrouping them in the color picture seen on the television screen. The thickness of the film on the glass determines which color will be reflected by the mirror. For the color blue, the thickness is about one-fourth the wavelength of blue light. To reflect green light, the film is made slightly thicker while red reflection requires the thickest films

High-Voltage Rectifier Equipment for Tube Testing

S. R. DURAND
MEMBER AIEE

MERCURY-ARC rectifier equipment of high capacity and voltage rating and special design for tube-testing service has been installed in the RCA-Victor Company Advanced Development Laboratory at Lancaster, Pa. The equipment provides 2,000 kw at 12,000 volts d-c with two rectifier units connected in parallel, and 2,000 kw at 24,000 volts d-c with the two units in series. In each case, the d-c windings of the rectifier transformers are displaced 30 electrical degrees so as to achieve, effectively, 12-phase rectification. The basic power circuit of the installation is shown in Figure 1.

An air-blast circuit breaker is used to connect the equipment to a 12-kv 3-phase 60-cycle power supply system. A high speed of response for tripping this circuit breaker under severe overload or fault conditions is attained by the use of an electronic circuit and a special trip coil. This trip coil is energized from a capacitor which is discharged under control of a thyratron tube. The thyratron is triggered by means of cold-cathode tubes, one of which will fire instantly when the overload current first reaches fault value in any one of the three phases of the incoming power supply line.

A wide range of voltage adjustment is provided by a step-type regulator connected between the circuit breaker and the paralleled a-c windings of the two rectifier transformers. This regulator has 32 positions so that voltage may be adjusted under load over a range from 20 per cent to full value in 320-volt steps.

The rectifier transformers are designed to operate normally with a 6-phase diametrical connection of the d-c windings. However, each phase is connected independently to high-voltage single-pole double-throw wall switches so that 3-phase Y series or parallel, 3-phase delta series or parallel, or 3-phase zigzag connections can be made for special testing conditions.

The mercury-pool rectifiers are of the pump-evacuated steel-tank type, and each 6-phase unit is mounted on an insulated frame which includes the control cubicle and a water-to-water heat exchanger. Auxiliary power is supplied through insulating transformers designed for 95-kv dielectric test between windings. Each anode of the mercury-pool rectifier units is equipped with two graphite grids. These grids are connected to phase-control circuits so that regulation of the d-c output voltage is not only provided by the step-type regulator but also by phase-control of the rectifier grids. A phase-shifter in each control cubicle is driven through an insulating coupling by a small motor mounted on a front grounded-steel control panel. Steep wave-front voltages are applied to the upper and lower control grids by thyratron tubes, and a slight angle of advance is maintained on the lower grid in relation to the upper grid in order to insure accurate firing control for precise voltage regulation.

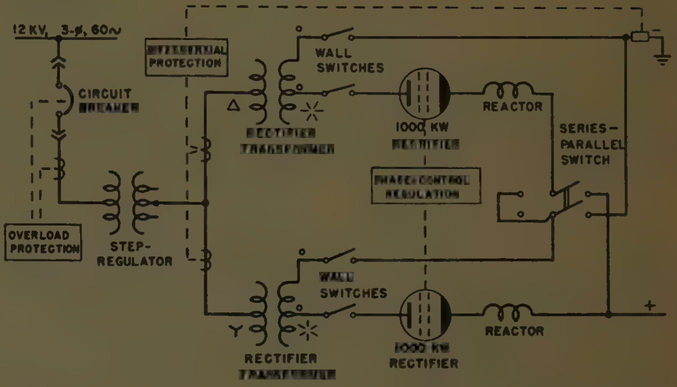

Figure 1. The basic circuit of the rectifier equipment. Phase control by means of grids in the mercury-arc rectifier units permits regulation to lower values or fine adjustment of voltage between steps of the regulator

When the step regulator is set for low-voltage operation, the per cent impedance of the regulator and transformers increases in value in comparison to full voltage operation so that it is essential to have a protection circuit to differentiate between normal overload and arc-back fault currents. Rectified direct current is obtained by means of current transformers and selenium rectifiers from the 3-phase a-c input side of each rectifier unit. This current is balanced against a d-c output current obtained from a shunt resistance. In case an arc back occurs, the currents from the a-c and d-c sides will be radically unbalanced so that a sensitive high-speed relay will operate to cause the a-c line circuit breaker to be tripped.

In addition to high-speed tripping of the main circuit breaker by means of the electronic overload protection circuit or the differential protection circuit, it is also possible with rectifier units of this type to utilize electronic circuits to prevent some of the main anodes from firing into a fault after it occurs. The anodes carrying current at the instant of a surge or overload will continue to carry the fault current until it is extinguished, but the other anodes that would normally conduct current in successive order can be prevented from firing into the fault.

Electronic control and protective circuits provide some of the most useful and important features of this rectifier installation which is essential for the development of new high-power radio-frequency tubes for radio and industrial applications. Mercury-pool rectifier units have proved to be reliable in performance and ideally suited for the diverse duty imposed on them in this type of testing service.

Digest of paper **50-145**, "High-Voltage Rectifier Equipment and Control for Tube Testing," recommended by the AIEE Committee on Electronic Power Converters and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Failures of Rubber Insulation Caused by Soil Microorganisms

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In some instances, where failures occur on rubber-insulated cables buried directly in the ground, it has been found that these cables have distinct regions of low insulation resistance. Laboratory tests have shown that these faults are caused by soil microorganisms which feed on natural rubber insulation or on minute veins of microbe food scattered in synthetic rubber insulation which itself is not attacked by the organism.

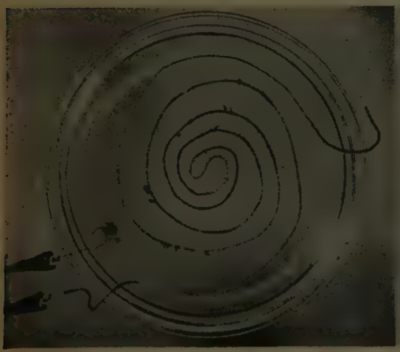
THE INVESTIGATION of the cause of the rare failures of nonleaded rubber-insulated cables buried directly in the ground was reported in an earlier paper.[1] These failures were characterized by localized regions of very low insulation resistance. The absorbed water content was no greater than in adjacent regions of high insulation resistance, and the physical properties were usually normal. Drying the failed insulation raised the resistance several decades, but brief exposure to moisture restored the low values. It was suspected that these failures had been caused by soil microorganisms.

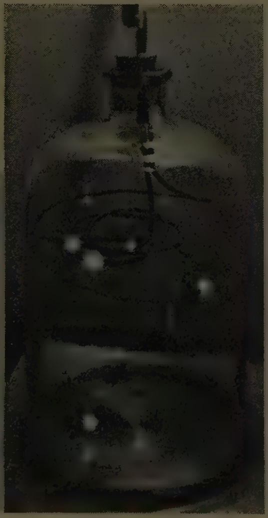
A study was made in the laboratory with conditions favoring microbial activity. By exposing thin walls of insulation to soil of high microbe content, adjusted to be neutral or slightly alkaline, and kept moist and warm, it was possible to accelerate the action so that failures like those occasionally found after ten or more years under actual service conditions were produced in a few weeks. Parallel tests in active soil, sterilized soil, and water showed conclusively that the drastic loss of insulation resistance in active soil was due neither to water absorption nor to the action of soil chemicals, but to attack by living microorganisms. In operation of underground cables the most favorable combination of conditions necessary for producing failure by microbial attack occur only rarely.

Since certain soil microbes can consume the natural rubber hyrocarbon, failure of natural rubber insulation is usually accompanied by visible surface pitting. Synthetic rubber insulation shows no visible signs of attack even after a 6-decade drop in resistance. This suggests some fundamental difference between the mechanisms of microbial attack on natural rubber and synthetic rubber.

Figure 1 (below). Locating faults with color indicator

Figure 2 (right). Locating faults by means of d-c corona





This article is concerned principally with these mechanisms and with the composition and structure that tend to make rubber insulation vulnerable to such attack. Experimental evidence is given to show that the *GR-S* and butyl hydrocarbons are not consumed by soil microorganisms, and that the invisible faults leading to electrical failure occur only where microbes eat out other materials present in the synthetic rubber insulating compound.

METHODS OF LOCATING FAULTS

To study the faults in rubber produced by microorganisms it is necessary to locate them precisely. Searching along a failed wire sample with a test probe is neither sensitive nor precise enough.

Use of Electrolyte with a Color Indicator. A simple method is to immerse the failed sample in an electrolyte containing phenolphthalein. The conductor is made negative to the bath. Voltages from 100 to 500 volts may be used. At any faults sufficiently leaky the development of alkali produces a red color. Figure 1 shows a failed sample on which 65 color spots could be counted.

D-c Corona Test. A more sensitive and rapid method is to stress a wet failed wire sample with about 5,000 volts (conductor negative) under reduced air pressure. Figure 2 shows a sample with five corona spots. The resistance of a single typical fault is of the order of ten megohms, whereas that of the surrounding intact region is usually of the order of 10,000,000 megohms per foot of sample. The leaky spots act like point electrodes to produce stress concentrations which break down the air near them. Considerably higher voltage is required to produce corona over all, so that the effect is clean-cut.

Essentially full text of paper 50-121, "Failures of Rubber Insulation Caused by Soil Microorganisms," recommended by the AIEE Committee on Insulated Conductors and approved by the AIEE Technical Program Committee for presentation at the AIEE North Eastern District Meeting, Providence, R. I., April 26–28, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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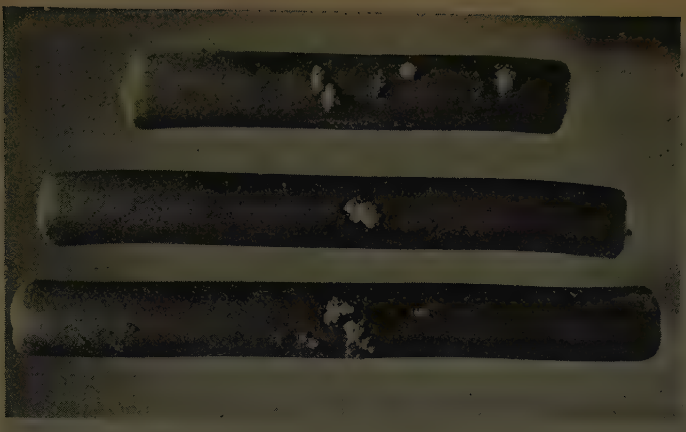

Figure 3 (above). Specks of metallic copper appear after several days in an electrodeposition test

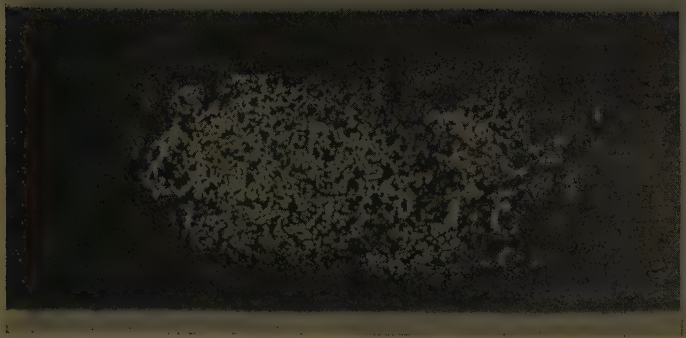

Figure 4 (below). Electrodeposited copper showing micropores in natural rubber insulation

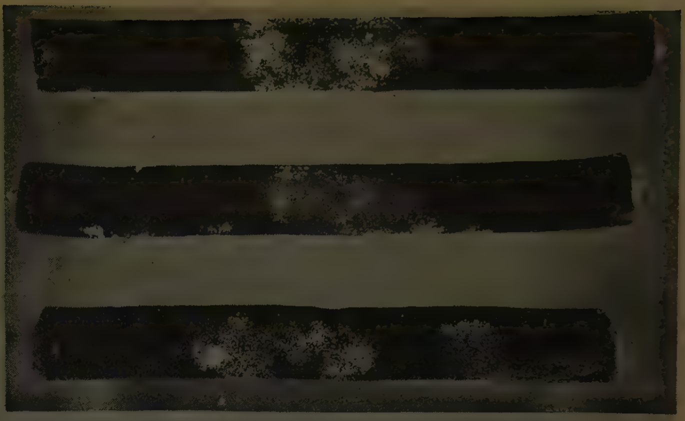

Figure 5 (above). Electrodeposited copper showing micropores in GR-S insulation

Figure 6 (below). Section of insulation of Figure 4 with copper deposits intensified by further plating

Electrodeposition of Copper in Faults. Some faults can be located and permanently marked by immersing failed wire samples in a copper-sulfate solution and making the conductor 100 to 500 volts negative to the solution. After several days surface specks of metallic copper appear at some of the faults (Figure 3). In some samples insulated with laboratory-mixed stock certain faulty regions showed hundreds of fine copper specks (Figures 4 and 5).

When the insulation was sliced off to various depths, particles could be found all the way through the wall. These were too minute to be seen by unaided eye, but their color made them visible at a magnification of 100 times. To obtain good photographs it was necessary to intensify the specks by additional plating (Figure 6).

Since the first copper ions have to traverse the wall of insulation before they are deposited, the copper filament grows from the conductor outwards. It is extremely fine. The copper-bearing channels are not always radial, but sometimes run in many directions, a fact which suggests the existence in the insulation, before microbial attack, of paths more vulnerable than the surrounding insulation.

The presence of invisible faults in failed *GR-S* insulations was demonstrated previously, but the structure of these faults was not established. Two alternatives were suggested, namely that these faults were either (1) regions of insulation degraded by diffused microbial products until the rubber there had extremely low resistivity, or (2) actual holes through the insulation. The results of the copper deposition test show that the faults are holes.

TWO TYPES OF MICROBIAL ATTACK

When wire samples which have failed in soil are inspected, the most obvious difference is that the surface of the natural rubber insulation is usually badly pitted, that of the *GR-S* insulation not at all. This suggests a fundamental difference between the modes of attack on the two types.

The severe microbial pitting so far found in natural rubber insulation, but not in the synthetics, is the more obvious action (Figure 7). Its progress can be noted visually long before there is any decrease in insulation resistance. Dielectric strength tests would be expected to show impending failure, but to produce drastic loss of sample resistance the microbes have to eat all the way through to the conductor. The breach in the insulation may eventually become a rather coarse hole rather than a micropore, since there is no reason for the microbes to prefer a radial direction when they can consume the insulation in bulk. It has been shown that a number of soil microorganisms can consume natural rubber either as the pure rubber hydrocarbon or as a part of a vulcanized compound. Unless a natural rubber insulation is protected by adequate preventives, the microbes can eventually eat through the wall. This type of attack appears to be little affected by differences in physical texture.

The mechanism of the microbial attack which creates micropores is more obscure. This occurs in both natural and synthetic rubber insulation. In natural rubber the microporous regions are much less numerous than the pitted regions, yet the samples fail through the micropores long before any pits reach the conductor. Figures 4 and 7 illustrate this point. They show two regions of a sample of natural rubber insulation which had failed in the accelerated laboratory soil test. The electrodeposited copper in Figure 4 shows the presence of many pores. Before the copper treatment this spot showed no visible signs of attack. This was the only microporous region observed. There were many pitted regions like those shown in Figure 7. Although these regions had been exposed to exactly the same conditions no copper specks were found in these pits nor signs of leakage by any other tests. The wall of insulation under the pits appears to have remained sound. To cause failure by pitting the microbes have to consume the insulation all the way to the conductor. This seems to be much slower than the one which creates the micropores.

Figure 6 shows the same microporous region as Figure 4 after 70 per cent of the wall had been sliced off and the copper filament ends, visible only after magnifying 100 times, had been intensified by additional copper plating.

Since microbial attack on *GR-S* insulation does not create pits, visual examination does not show whether it has failed. Failure is detected by loss of insulation resistance. To locate the faults one of the tests described in the foregoing paragraphs is required. Samples of failed *GR-S* insulation which had suffered a loss of resistance of six decades or more still showed a smooth, shiny surface. The micropores were revealed only by the electrodeposited copper.

In failed *GR-S* insulation the absence of surface erosion, the random direction of the pores, and their minute size imply that the insulation is not uniformly vulnerable, but that even before exposure to soil microorganisms, it contains imperfections in otherwise inert material. These are minute veins of microbe food scattered in a random manner throughout a medium that microbes cannot consume. This microbe food is neither water-soluble nor hygroscopic, since control samples in water maintain normal resistance indefinitely. Soil microbes eat out the insoluble food and leave in its place some hygroscopic material. This makes the resistance of the pores very low when the sample is wet, but very high when it has been allowed to dry.

EVIDENCE OF IMPERFECTIONS

There is a variety of evidence for the existence of these imperfections. If the bulk insulation could be consumed by soil microorganisms, we should expect, after prolonged soil exposure and failure, to find both severe surface erosion and much larger pores. There would also be no reason for the peculiar orientation and zigzag course of the pores so often observed when samples are examined after copper deposition. The electrical evidence relating to these imperfections is especially interesting. Considerable light is thrown on the probable structure both by the trend of insulation resistance versus soil exposure when the test is continued several months after initial failure, and by d-c breakdown values on samples simply soaked in hot water.

Figure 7. Characteristic pitting of natural rubber insulation attacked by soil microorganisms

Figure 8 shows the peculiar trend of resistance of *GR-S* insulation when exposure to soil is continued after failure. These accelerated laboratory soil exposure tests were made on ten samples of Number 14 solid wire with a 3/64-inch wall of a *GR-S* compound having low water absorption. The samples were consecutive 5-foot lengths from the same length of wire run in the factory. Ten samples in soil all failed in ten months or less. Four control samples in water maintained normal resistance.

The course of the attack is presumably as follows. Some soil microorganisms, not yet identified, consume food in the minute streaks. Until the first micropore reaches the conductor the effect on the sample resistance is negligible. As soon as the pore passes all the way through the wall, the resistance drops several decades. After this first drop the decrease is very gradual. As more pores traverse the wall they decrease the resistance relatively little. For example, ten faults having equal leakage lower the sample resistance only one decade more than a single fault. If a pore kept increasing in diameter because the microbes could consume the surrounding medium the sample would soon be practically short circuited. This leveling off of the sample resistance after the first sharp decrease, together with the minuteness of the pores and the absence of any surface erosion, seem to be proof of the correctness of the postulated structure of the imperfections.

There is other independent evidence. Visual tests described later in this article show that the *GR-S* hydrocarbon does not support microbe growth, but that raw *GR-S* contains materials that do. These materials and others added in the compounding are believed to be the food in the imperfections.

EFFECT OF PROCESSING ON *GR-S* INSULATION

Whether a given rubber insulating compound is processed in the factory or in the laboratory the regular physical and electrical tests usually show no significant difference in quality. In the soil-exposure tests, if the insulation is not inherently resistant, or made so by the addition of effective preventives, wire samples made in the laboratory have almost invariably proved to be more vulnerable than those made in the factory. Thus the structure, as influenced by the processing, that is, the thoroughness and uniformity of mixing, is an important factor in determining the stability in soil.

One of the most effective ways of testing rubber insulation for structural imperfections not revealed by low resistance is to make d-c breakdown measurements on samples which have been soaked several days in hot water. If fissures, micropores, or poorly bonded interfaces extend only partly through the wall, their effect on the insulation resistance may be negligible. Direct voltage stress causes breakdown at the weakest spot. It is a local, not a bulk, effect. After a few days soaking in water at 158 degrees Fahrenheit an imperfection in only a fraction of the wall thickness can lower the d-c breakdown considerably. Water which diffuses to an imperfection acts like a sharp electrode to produce high local stress concentration and breakdown.

In the following experiment, *GR-S* insulation having abnormal vulnerability to soil microbes also showed low d-c breakdown strength. Samples were prepared of Number 14 solid wire with 3/64-inch wall of *GR-S* insulation having low water absorption. The formulation was identical in all samples, but the processing in the three groups differed as noted in Table I.

Table I. Effect of Processing on Stability and Breakdown

Laboratory Mixed and Insulated	Factory Mixed Laboratory Insulated	Factory Mixed and Insulated
Initial Megohms in Soil		
2,700,000	2,100,000	2,500,000
2,700,000	2,200,000	3,000,000
2,700,000	2,300,000	3,100,000
2,900,000	2,200,000	3,500,000
Megohms after 4 Months in Soil		
400	3,300,000	2,000,000
6	2,900,000	2,100,000
3	3,100,000	2,300,000
4	700	2,400,000
Volts per Mil—D-C Breakdown after 3 Days in Water at 158°F		
750	1,000	1,100
750	1,200	1,200
700	1,100	1,300
700	1,200	1,200

The usual tests for insulation resistance versus soil exposure were made on samples from each group. Table I shows the initial resistance and the resistance after four months in soil (five feet buried length). Another set of samples was soaked three days in water at 158 degrees Fahrenheit and then broken down by d-c stress.

Control samples for the soil tests showed no drop in insulation resistance in water. Samples from each group, after being dried two days at 185 degrees Fahrenheit, showed an average value of 2,300 volts per mil; apparently they were not significantly affected by the variations in processing. Thus the major physical factor affecting both stability in soil and d-c breakdown strength is the completeness of mixing. Although the low d-c breakdown voltages and the rapid failure in soil may not both be caused by the same imperfections, it is evident that the kind of mixing that produces the highest d-c breakdown after hot soak also increases the stability in active soil. It is not surprising that the factory mixing should prove superior.

The difference with regard to stability in soil is one of degree only. The results in Figure 8 and those in the third column of Table I were obtained with samples from the same length of factory-run wire. The better mixing thus merely delayed failure. It seems unlikely that any amount of mere physical processing would guarantee unlimited stability in service lengths of thousands of feet, which a few microbe faults might put out of operation. On the other hand, certain types of *GR-S* insulation made inherently resistant by the addition of effective microbe preventives have been stable in soil even when the processing is not thorough enough to produce optimum d-c breakdown strength after hot-water soaking. The d-c breakdown strength after hot-water soaking is thus an index of structural integrity, regardless of resistance to microbe growth. The visual fungus test described later shows whether the material is resistant to microbe attack without regard to the thoroughness of mixing. These two tests are entirely independent.

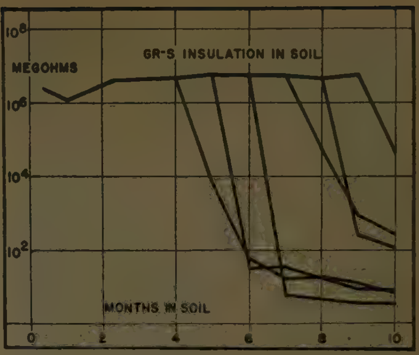

Figure 8. Dielectric resistance versus time of exposure to soil of a 3/64-inch wall of GR-S insulation on a Number 14 solid wire

The ideal insulation is one combining maximum resistance to microbe growth with the best possible physical structure.

PROTECTION OF INSULATION BY JACKETS

Tough neoprene jackets are commonly used over the insulation of nonleaded underground cables to provide mechanical protection and weather resistance. It is desirable that they should also protect the insulation against attack by soil microorganisms. It is not satisfactory to test the resistance of neoprene jacket compounds to microbial attack by extruding them directly on a copper conductor and measuring insulation resistance versus soil exposure. The resistivity of such compounds is inherently low, and this tends to mask the effect of failures produced by microorganisms.

The most significant laboratory test is carried out by coating wire with insulation known to be susceptible to microbes, applying a layer of neoprene compound over this, burying the samples in soil, and making periodic resistance measurements between conductor and soil. The resistance of the jacket is so low that it does not interfere with the measurement.

Since two different mechanisms of attack had been observed in the failures of natural rubber and *GR-S* insulation, it was of interest to test the effect of neoprene jackets over both types. Ten 5-foot samples of Number 14 solid wire with 3/64-inch wall of a natural rubber insulation and a 25-mil wall of neoprene jacket compound were buried in soil and four were immersed in water. Those in water showed normal high resistance during 13 months. All ten soil-test samples failed in nine to thirteen months with an average drop in insulation resistance of three decades. This is less than that observed when the insulation is directly exposed to soil. Even an imperfect jacket delays the attack and restricts it to a small fraction of the total area. These failures indicate that the microbes traverse

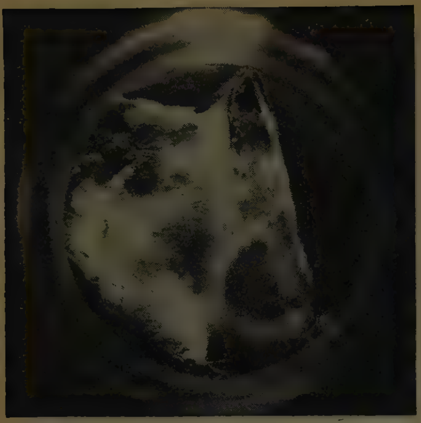

Figure 9. Fungus on an unmilled lump of GR-S compound after several weeks' exposure to inoculated water

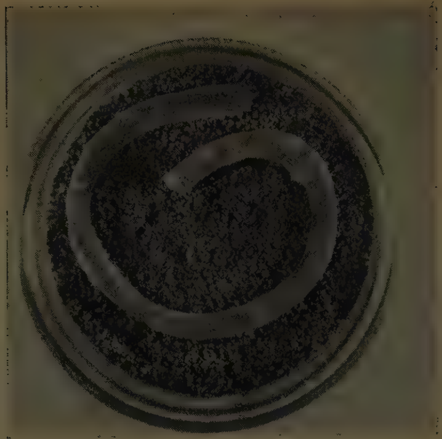

Figure 10. Visual fungus test on GR-S Compound A showing growth of fungus in one week

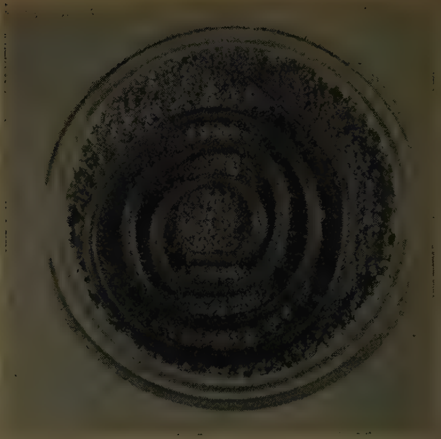

Figure 11. Visual fungus test on GR-S Compound B showing no fungus during a 9-month test

the neoprene jacket, presumably through food streaks or imperfections. When they reach the natural rubber they can cause failure by consuming the bulk insulation.

In a parallel test ten samples with similar jackets, but with *GR-S* insulation, showed no decrease in resistance during fifteen months in soil. Four control samples in water also maintained normal resistance. Two samples of the same *GR-S* insulation without jackets showed normal resistance for ten months but drops of four to six decades after thirteen months.

The marked difference in relative stability of the *GR-S* and the natural rubber insulation under neoprene jackets of identical type is most easily explained by applying the imperfection theory to the case of two layers. Since microbes cannot consume the bulk material of either neoprene or *GR-S* they have to find imperfections in both to cause failure. Even when these are numerous the probability of an imperfection in the jacket registering exactly with one in the insulation is small. If this does happen the sample should eventually fail. In general, the imperfections would be expected to be staggered in such a way that failures in jacketed *GR-S* samples would be rare.

The statement in the earlier paper that neoprene compounds appear to be inherently resistant to soil exposure is true only in the sense that, like *GR-S*, they do not show visible results of microbe attack. If a neoprene jacket contains food streaks, microbes can eat through it and attack susceptible natural rubber under it.

In a preliminary experiment samples of wire insulated with a 15-mil wall of vulcanized latex covered with a 20-mil wall of a neoprene jacket compound were exposed to soil until they had failed. The jacket was stripped from short pieces and these were quickly placed on sterile nutrient agar. In a few days white colonies starting from the wire spread gradually over the agar surface. The microorganism was identified as a species of Fusarium. Experiments of this type are valuable to show that microbes can traverse the jacket and to identify those that do.

ACCELERATED TEST OF MICROBIAL ATTACK

The decisive laboratory test of the stability of underground cable insulation is the periodic measurement of insulation resistance of samples buried in soil for long periods under conditions most favorable to microbial attack. In this test susceptible samples fail in a few months. As compounds more resistant to soil exposure are developed the time to failure becomes excessively long. A means of quickly showing whether a compound is inherently resistant to soil microbes is of great advantage.

A simple visual test provides such a means. Small pieces of material, which may be either vulcanized insulation or raw rubber or other polymer, are placed on a thin layer of soil sprinkled over moist sand. The test may be accelerated by dusting the sample lightly with dried soil. The amount of material for such a test is very small and much processing time is saved.

Most susceptible materials show considerable fungus growth in a week or two. For example, the *GR-S* insulation on the samples of Figure 8, some of which took ten months to fail electrically, showed profuse fungus growth in about two weeks on the visual test. This test shows whether the insulating compound is inherently resistant and is independent of the degree of mixing.

Figure 9 shows an unmilled lump of *GR-S* after several weeks in a closed bottle over inoculated water. Without other tests the profuse growth of fungus on the raw *GR-S* could be misleading. When the same type of *GR-S* has been acetone extracted it shows no fungus growth after many months on this test. Even if the *GR-S* is badly oxidized after extraction by prolonged heating, it does not support growth. The *GR-S* hydrocarbon is not a source of microbe food. When the acetone extract is evaporated on aluminum foil and exposed to soil, heavy fungus growth appears. The immunity of purified *GR-S* supports the imperfection theory of failure of *GR-S* insulation. It accounts for the absence of surface erosion.

Growth of fungus on a particular insulation in the visual test does not prove that failure in soil of that insulation was directly caused by fungus. The fungus serves as an indicator which shows whether the compound is attractive to microorganisms in general. In doubtful cases the visual test may not be a sufficient criterion. On the other hand, an insulation that supports profuse fungus growth would be a poor risk for underground cable insulation. A large number of unpromising materials can be screened out with little effort. To date the routine soil-exposure tests on rubber insulation have confirmed the predictions of the visual test.

A practical application of this test is illustrated in Figures 10 and 11. Both samples have similar *GR-S* insulations of low water absorption, but with different combinations and amounts of preventives. Compound *A* showed visible fungus growth in one week. Compound *B* showed no growth during a 9-months' test. Thus the implication of the visual test was that compound *A* would be unstable in soil, *B* stable.

To check this, samples of each type were buried in active soil. Control samples in water and in sterilized soil have maintained normal resistance for a year. In active soil all samples of compound *A*, which showed fungus in the visual test in one week, failed within five months. Samples of compound *B*, which showed no growth on the visual test, have maintained normal high resistance for one year. These results confirmed the predictions of the visual test for these particular compounds.

A similar confirmation was obtained with ten natural rubber samples jacketed with a particular neoprene compound. The jacket showed profuse fungus growth on the visual test. All ten samples failed in the accelerated soil-exposure test.

It is not safe to use the results of visual fungus tests on individual compounding ingredients to predict the stability of complete insulating compounds. For example, although raw neoprene shows no fungus growth in this test, a typical neoprene jacket compound may support profuse growth within a week. Certain insulating compounds may show no growth in the unvulcanized condition, but abundant fungus after vulcanization. The interaction of compounding ingredients during vulcanization may change the susceptibility to microorganisms. The only safe test is one made on the final insulation. If a compound shows no appreciable fungus growth, the visual test should be followed up by periodic measurements of insulation resistance on wire samples in soil.

Pure natural rubber hydrocarbon supports growth of microorganisms. In the visual test the first growth seems to be Actinomycetes appearing wherever the sample contacts the soil. This is followed by fungus growth. Raw butyl rubber generally shows little or no fungus growth. A slight growth of an organism cultured and identified as a species of Tricoderma was observed on some samples, but acetone-extracted butyl rubber shows no growth at all. Butyl rubber severely oxidized after acetone extraction also fails to show growth of fungus. Paraffin wax and Heliozone show excessive growth. A high paraffin content tends to make compounds more susceptible to microbial attack. In neoprene compounds the effect of paraffin is peculiar. It blooms rapidly to the surface where it supports heavy fungus growth. A number of preventives that are effective in insulating compounds do not inhibit such growth on neoprene compounds, presumably because they are not sufficiently soluble in the paraffin layer. They may also reach the surface more slowly than the paraffin. If the microorganisms merely ate off the paraffin film without further action, this would not be cause for concern. It is not safe to rest on that assumption. This is shown by the failure of the samples jacketed with neoprene compounds that showed fungus growth in the visual test.

SUMMARY

The failure of rubber insulation caused by soil microorganisms can best be detected by a decrease of several decades in the insulation resistance. To study the mechanism of attack and the physical structure that makes rubber insulation vulnerable to such attack it is necessary to locate and mark the failed spots. Several methods of doing this have been described. The electrodeposition of copper in the micropores created by microbes affords the most insight into the physical structure of the faults. Two distinct modes of attack have been shown. The simpler one, characteristic of natural rubber, is a progressive eating away of the bulk insulation. The second, more obscure type, creates micropores through the wall, without visible surface erosion. This mode is typical of synthetics in which the base hydrocarbon or polymer does not support microbe growth. The imperfections consist of minute streaks of microbe food scattered in a random manner through otherwise inert material.

As a quick preliminary measure of the resistance of a material to soil exposure the simple visual fungus test is very convenient. As a criterion of stability this has so far been confirmed by the routine resistance tests after accelerated laboratory soil exposure. It is not safe to predict the stability of a complete compound from the results of visual tests on the base material. The vulcanized insulation must be tested. Insulating compounds shown to be promising by the visual test should be given a prolonged soil exposure test.

The testing of preventives in rubber is not simple. Materials which are strongly antiseptic in water may not be so when mixed in a rubber compound. Many are completely unsuitable in rubber insulation. Some preventives are effective in a compound before it is vulcanized but not afterwards. Some are completely inactivated by certain other necessary or desirable ingredients. Others may leach out in time and cease to protect the material. Oxidation inactivates some preventives. A nicely balanced compound is required to produce insulation with sufficient stability in soil, proper physical characteristics, and high electrical quality.

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Conversion Unit For Projecting 3- by 4-Foot Television Pictures

W. L. MANNING

This article describes an auxiliary type of television equipment, known as the Norelco Protelgram projection system, which presents the viewer with a 3- by 4-foot television picture. The system can be used with any standard 10-, 12$^1/_2$-, or 16-inch table-model television receiver.

PRIOR TO THE advent of common television usage, pictures in the home became popular by the use of home-movie projectors. By a process of evolution the 3- by 4-foot home-movie picture size became an accepted one. These facts would indicate a preference for picture sizes of this order, at least for some types of picture presentations.

When home use of television became a reality, circumstances caused small pictures to be presented to the public. They were accepted then, but a steady trend to larger pictures is now apparent. Some television receivers have been manufactured which produce a 3- by 4-foot projected picture using a standard home-movie viewing screen. These receivers, as well as home movies, are limited to operation in extremely low ambient light. This limitation does not seem to be well accepted by the public. The problem of presenting a 3- by 4-foot television picture is therefore difficult to solve. One solution is presented here.

It is obvious that any such picture presentation in the home should be in the auxiliary type of equipment and should complement the normal television picture. The Norelco Protelgram projection system offers considerable advantages in solving this problem. The compactness and deflection sensitivity of this system make the design of the unit described here possible.

The Protelgram unit selected for this design utilizes a 90-inch "throw distance" to produce a 3- by 4-foot picture. It includes a pulse-type well-regulated 25-kv anode power supply and *3NP4* projection cathode-ray tube with associated yoke and focus coils.

The requirements of a television receiver to operate a Protelgram system are stated as compared to a *10BP4* receiver in Table I. In addition, the Protelgram system requires 1.2 amperes at 6.3 alternating volts and 50 milliamperes at 350 direct volts as power for the 25-kv supply.

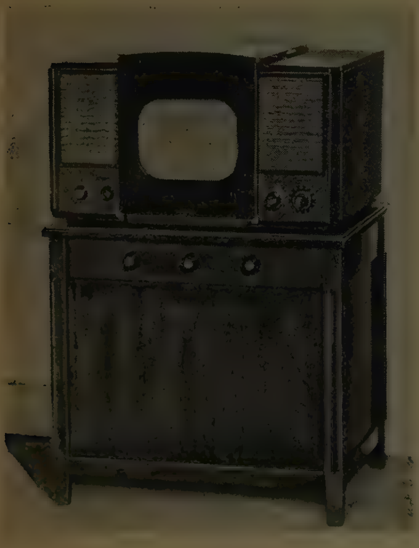

Figure 1. Front view of the complete Duo-Vue conversion unit with television receiver attached

Table I. Receiver Requirements*

	10BP4	Protelgram
Video output	60 volts, peak to peak	100 volts, peak to peak
Horizontal deflection current	470 milliamperes, peak to peak	400 milliamperes, peak to peak
Focus current	115 milliamperes	121 milliamperes
Ion-Trap	109 milliamperes	Not required
Automatic biasing	Not required	Required
Flyback high-voltage	Required	Not required

* Values are approximate and vary for certain conditions. Tabulated values show requirements with standard components.

It can be seen then that an auxiliary unit can be designed to adapt and convert a standard 10-inch television receiver to a projection set using this system. Also, it is apparent that by proper use of such an auxiliary unit together with a switching arrangement, it is possible to switch from the direct-view picture to the projected picture. The basic requirements for a unit to convert standard television receivers to projection pictures of 3- by 4-foot size by switching are therefore available to the design engineer.

In order to design a commercially feasible conversion system, the following design requirements are indicated:

1. Cabinet should be small and easily movable from place to place in the user's home. Its general layout should be as simple as possible.

2. Electrical requirements should be such that by simple connections to a standard 10-inch, 12$^1/_2$-inch, or 16-inch table-model television receiver, the unit would perform the following functions:

(*a*). Amplify and recompensate the video output for the Protelgram Projection System used.

(*b*). Supply 350 direct volts at 50 milliamperes.

(*c*). Supply 6.3 alternating volts at 1.2 amperes.

(*d*). Supply a range of focus current from 90 to 150 milliamperes.

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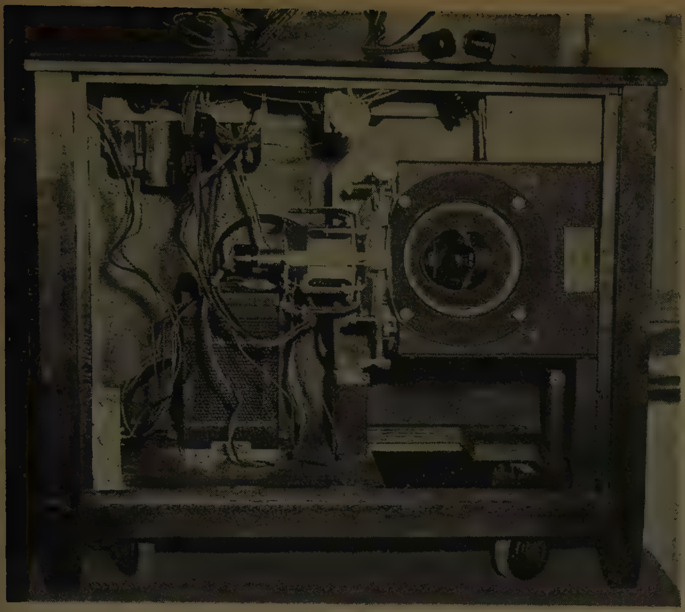

Figure 2. Rear view of the complete Duo-Vue conversion unit

(*e*). Incorporate an automatic biasing circuit to cut off the *3NP4* tube if receiver deflection circuits should fail.

(*f*). Arrange a switching and deflection control circuit for selection of the picture desired.

GENERAL DESIGN

THE DESIGN is accomplished satisfactorily in the Norelco Duo-Vue product. An auxiliary chassis, a function switch, and a complete projection system are housed in a cabinet which is styled to be utilized as a table-model television-receiver support. Figure 1 shows the completed conversion unit with television receiver attached. The unit is mounted on concealed casters so that it may be rolled away from the wall when the 3- by 4-foot picture projects from the rear of the cabinet. Figure 2 shows the rear cover removed from the cabinet and the placement of parts within the cabinet. The Duo-Vue is placed against the wall during normal small-picture viewing and is rolled away from the wall to project its large picture on a movie screen or other suitable viewing area 90 inches distant. Optical focusing is obtained by rolling the unit toward or away from the viewing screen. This adjustment is not critical. Optimum focus is obtained within a range of several inches. The unit is designed to be attached to the television receiver by cables incorporating disconnect plugs and sockets.

ELECTRICAL DESIGN

A BLOCK diagram of the system is shown in Figure 4. The chassis (Figure 3) is of compact design, measuring $7^1/_2$ by $5^1/_2$ by $2^1/_4$ inches. The schematic (Figure 5) shows the circuit used in the complete Duo-Vue unit. Loctal tubes are utilized because of their obvious advantage in inverted position use.

Video Amplifier. One stage of video amplification is used to obtain adequate video drive and also to compensate for added cable and switch capacity in the system. Shunt, series, and cathode-regeneration peaking are utilized to obtain excellent video response. A slight rise in the response curve in the 4-megacycle region actually improves the apparent resolution in the 3- by 4-foot picture over the original direct-view picture in many cases. The gain of the *7C5* video amplifier is in the order of 2.8 to 1 and is selected so that adequate video will be applied to the *3NP4* tube from practically any television receiver. The signal is injected into the *3NP4* cathode because of the phase reversal obtained in the video amplifier. The *3NP4* cathode-heater potential is maintained within limits by use of a separate transformer heater winding connected to the plate side of the video-amplifier load resistor. Capacity loading is eliminated by using a 1-megohm resistor for isolation.

Low-Voltage Power Supplies. The power requirements for the amplifier, focus current, Protelgram high-voltage unit, and biasing circuits are supplied by a transformer and a *7Z4* fullwave rectifier, together with a completely isolated half-wave selenium rectifier. The *7Z4* supplies 350 direct volts at 70 milliamperes. This current is split up between the high-voltage unit and the internal chassis requirements. The video amplifier utilizes approximately 30 milliamperes and the high-voltage unit approximately 40 milliamperes. Normal capacity input-choke type filtering is used in this supply.

The half-wave selenium rectifier supplies a maximum of 150 milliamperes of focus current. This rectified voltage is also used as a bias voltage when the direct-view tube is switched off during projection performance, as will be noted later. Resistance-capacitance filtering is used in this supply and is sufficient to reduce effectively the focus-current ripple.

Automatic Biasing Circuit. A *7B6* dual diode-triode is utilized in this circuit. As can be seen by examining Figure 5, each diode of this tube is furnished with pulses derived from the deflection circuits, both vertical and horizontal. Rectified negative voltages from each diode are added and supplied to the control grid. Positive

Figure 3. Duo-Vue conversion unit chassis

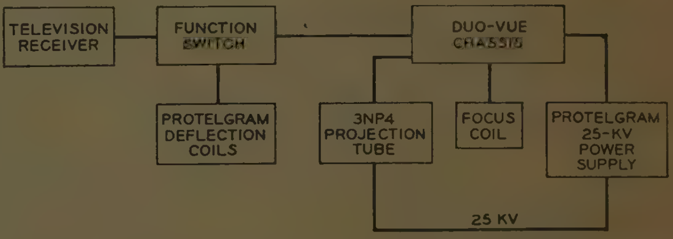

Figure 4. Block diagram of the Norelco Protelgram projection system

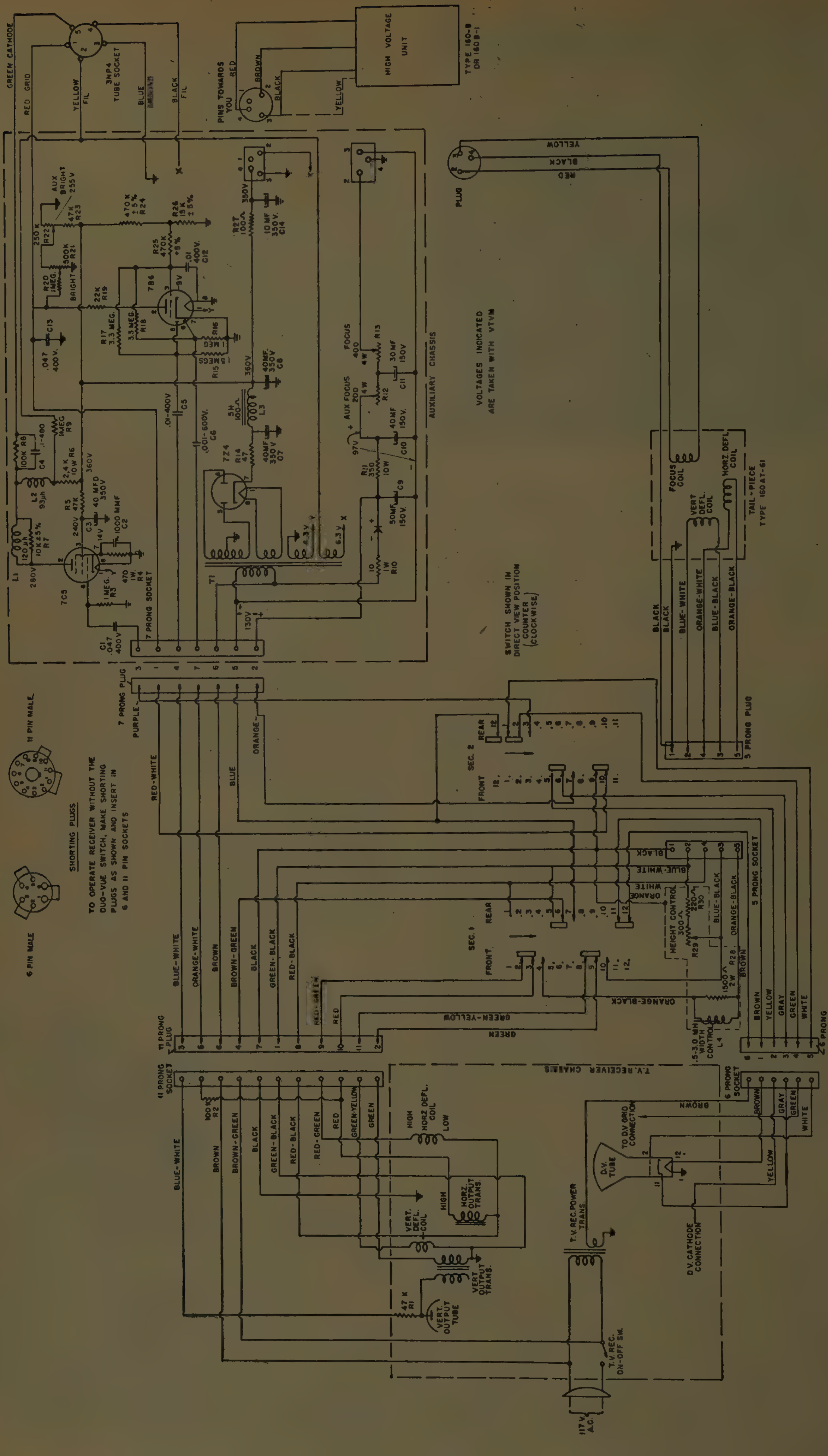

Figure 5. Schematic of Duo-Vue conversion unit

"bucking" voltage is then applied at the control grid until the resulting grid voltage during normal set operation is approximately minus nine volts. The plate current of the triode section is effectively cut off when operating in this condition. The plate of the triode section is connected to the *3NP4* grid through a 22,000-ohm resistor. The triode plate voltage and the *3NP4* grid voltage are derived through a high-impedance circuit (one megohm). A failure of either the horizontal or vertical sweeps will allow the triode grid to approach zero bias. The triode section will conduct and the *3NP4* grid voltage will be reduced to a point near zero. This effectively increases the *3NP4* bias beyond cutoff, thus reducing the possibility of sweep burns.

Function Switch. A 2-section range switch is used. It switches video, deflection coils, alternating current, picture-tube bias, and direct-view cathode-ray tube grid, cathode, and heater. In the case of video, it merely connects the video output of the set to the direct-view tube or the input of the Duo-Vue amplifier. The switch is physically positioned at the center and extreme rear of the unit, which places it immediately under the direct-view tube socket in most receiver designs. This position is selected to reduce lead capacity. In "direct-view" position the direct-view tube is connected normally. In "projection" position, the direct-view heater, cathode, and grid are opened, and bias voltage from the selenium rectifier is applied to the grid and cathode to cut off residual spot emission. When switching from "projection" to "direct-view," the *3NP4* tube is biased beyond cutoff by simply grounding its grid. The deflection energy is transferred from the direct-view to the Protelgram deflection coils by short-circuiting-type switches. This insures ample load on the receiver output transformers at all points of the switching sequence. The function switch assembly is designed to be the central connector for all units. Two cables are installed in the television receiver and fitted with connectors which, in turn, are mated to the switch assembly. The Duo-Vue chassis and projection deflection yoke are plug connected to the switch.

The unit contains front panel brightness and focus knobs and auxiliary brightness and focus controls. This method of design is selected to make the front-panel controls of the vernier type and simple to operate. Height and width controls for the projected picture are incorporated as service controls. These controls are of the attenuator type. This is made possible by the excellent deflection sensitivity of the Protelgram system. More than adequate sweep is obtained from any 10-, $12^1/_2$, or 16-inch picture-tube set. The height control is a simple resistive shunt across the vertical deflection coils. The width control consists of a permeability tuned coil in series with the horizontal deflection coils. The inductance is damped by a resistor to prevent ringing.

Sockets are provided on the Duo-Vue chassis for easy connection of the focus coil and high-voltage unit.

The Duo-Vue unit has been operated with television receivers of many makes and prices. It has successfully produced a fine quality 3- by 4-foot picture, and has apparently not reduced the picture quality of the television receiver. The highlight brightness of the 3- by 4-foot picture measures approximately three to four foot lamberts. The resolution of the picture has been measured at 425 lines and has always shown itself, in tests, to be as good or better than the direct-view picture of the receiver.

A Duo-Vue is simple to operate and after proper installation, adds little more adjusting than the original receiver required.

It is believed that this instrument will do much to interest the small picture television-set owner in real large-screen television since it can be purchased and installed at low cost.

Answers to Previous Essays

Polarization or Charge in a Dielectric? The following is the author's answer to his previously published essay (*EE, Aug '50, p 710*).

It is evident that to answer the question raised we must somehow probe into the dielectric itself. Examination of the external field alone cannot give the desired information, since for any distribution of polarization density **P** within a body which gives a particular external field **E** there is a possible distribution of charge density ρ namely $\rho = -\text{div}\ \mathbf{P}$ which will give exactly the same external field. Probing into the dielectric means drilling little holes or milling little cuts into it, and inserting instruments of some sort to determine the electrical conditions in these holes or cuts. According to Faraday's and Maxwell's views these "electrical conditions" are completely described by knowledge of the electric and magnetic fields existing within these holes and cuts. We are thus led to the Kelvin Cavity definition of the electromagnetic field within matter, which is essentially the only satisfactory operational definition, for macroscopic electromagnetic theory.

Returning to our wax, we determine that its total charge is zero by integrating the normal component of the electric field over a surface surrounding it and lying in empty space, where the electric field is defined through the force on a small charged probe. This integral, which equals $4\pi Q$ where Q is the (thus defined) total charge on the wax body, will be zero in this case. Now to determine whether any part of the wax has a charge we cut the wax up into small parts by fine cuts as in Figure 1, and assume that we do this so skillfully that we do not affect the electrical field outside. We assume then that we have also not affected the charges or polarizations of the individual parts of the wax. Now to find out whether any particular small

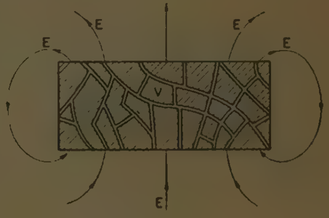

Figure 1. Wax cut into small volumes

part V has a total charge on it, we surround it by a surface S^*, lying wholly within the narrow cut around V, and integrate $\mathbf{E}_n^*$, the normal component of the electric field within the cut over the surface S^*, obtaining

$$\int\int \mathbf{E}_n^* dS^* = 4\pi q. \qquad (1)$$

q, we define as the real or true charge on the volume V.

We are thus led to study the electric field $\mathbf{E}^*$ in narrow cuts within the material. At any point in the material, $\mathbf{E}^*$ will depend on the state of electrification of the material, but it will also depend on the particular orientation chosen for the cut at that point. If this orientation is varied, $\mathbf{E}^*$ will vary, and also particularly $\mathbf{E}_n^*$ will vary. If however, the integral of equation 1 is to be proportional only to the volume of V, and not be dependent on its shape, then it may be shown that $\mathbf{E}_n^*$ is the normal component of a vector $\mathbf{D}$ which does not change as the orientation of $\mathbf{dS}^*$ is changed. This vector $\mathbf{D}$ we call the electric induction, which is thus defined as having the same normal component as $\mathbf{E}^*$, the field within a narrow cut.

D is defined by

$$\mathbf{D}_n = \mathbf{E}_n^* \qquad (2)$$

If now ρ the charge density is q of equation 1 divided by V, we may equivalently say that ρ is defined by

$$4\pi\rho = \text{div } \mathbf{D} \qquad (3)$$

Studying E^* further, we should expect that since it is in empty space, we should have

$$\int_0 \mathbf{E}^* dS = 0 \qquad (4)$$

where the integral of equation 4 is taken around any closed curve lying in the cut. It follows then that $\mathbf{E}_s^*$ is the s component of a vector $\mathbf{E}$ which at any given point does not change as the orientation of the cut in the material is changed. This vector $\mathbf{E}$ we call the electric field or intensity, which is thus defined as having the same component parallel to the cut, of $\mathbf{E}^*$, the field within the narrow cut; that is, $\mathbf{E}$ is defined by

$$\mathbf{E}_s = \mathbf{E}_s^* \qquad (5)$$

Finally, for the polarization, **P** is defined by

$$\mathbf{D} = \mathbf{E} + 4\pi\mathbf{P} \qquad (6)$$

By making cuts in the wax, then, and observing the fields in the cuts, and using equations 1 through 6 we may answer the question raised in the essay.

This method of defining the electromagnetic field within matter by means of the fields observed within fine cuts can be extended without change directly to the general case for material media at rest provided there are no conduction currents. To meet the condition of conduction currents we need to postulate that we can introduce cuts of such short time duration of existence, that they do not affect the electromagnetic field; that is, that they do successfully define unique vectors E, D, H, B, and so forth. We would then have **D** defined by

$$\mathbf{D}_n = \mathbf{E}_n^* \qquad (2)$$

E is defined by

$$\mathbf{E}_s = \mathbf{E}_s^* \qquad (5)$$

P is defined by

$$\mathbf{D} = \mathbf{E} + 4\pi\mathbf{P} \qquad (6)$$

ρ is defined by $4\pi\rho = \text{div } \mathbf{D}$ (3)

B is defined by

$$\mathbf{B}_n = \mathbf{H}_n^* \qquad (7)$$

H is defined by

$$\mathbf{H}_s = \mathbf{H}_s^* \qquad (8)$$

M is defined by

$$\mathbf{B} = \mathbf{H} + 4\pi\mathbf{M} \qquad (9)$$

i is defined by

$$\frac{4\pi}{c}\mathbf{i} = \text{curl } \mathbf{H} - \frac{1}{c}\frac{\partial \mathbf{D}}{\partial t} \qquad (10)$$

Maxwell's equations then further assert that

$$\text{div } \mathbf{B} = 0 \qquad (11)$$

$$\text{curl } \mathbf{E} = -\frac{1}{c}\frac{\partial \mathbf{B}}{\partial t} \qquad (12)$$

and it follows that

$$\text{div } \mathbf{i} + \frac{\partial \rho}{\partial t} = 0 \qquad (13)$$

For moving media, the definitions of E, D, and so forth need to be modified, but that is beyond the scope of the present essay.

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A Paradox? The following is the author's answer to his previously published essay (*EE, Aug '50, p 710*).

The transformer operates with one primary winding supplied from 12 kv single phase and the other two windings supplied in series from the same source.

Normal voltage transformation ratios must apply between any one primary winding and its corresponding secondary for the flux lag in any leg of the core is common to both windings. As V_{AN} is the only normal secondary voltage, then winding x must be the only primary supplied with 12 kv. Fuse 3 must therefore be the one blown.

As normal flux must be maintained for winding x, the algebraic sums of the fluxes through y and z must equal that through x. Thus $V_{BN}+V_{CN}=V_{AN}$, from which $V_{BN}=24$ volts.

Furthermore, as $\theta_y+\theta_z=\theta_x=$ a constant, $\Delta\theta_y=-\theta_0$. It follows that $I_B=I_C=40$ amperes, and that $R_B=V_{BN}/I_B=0.6$ ohm.

When our trouble-shooter removed low-voltage fuse B, I_B fell to zero. I_C in consequence fell to zero. At the same time V_{CN} fell to zero and V_{BN} rose to 120 volts. Had both B and C phase low-voltage fuses been removed at the same time, the corresponding terminal voltages at the transformer would have adjusted themselves to 60 volts each. In practice there is usually a slight discrepancy—for example, say 59 and 61 volts due to unequal flux paths through the core.

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Underground Hydroelectric Power Stations

AKE RUSCK G. WESTERBERG

THE NATURAL waterfalls in Sweden are often very extended in length. The utilized head in the power stations is frequently less than 150 feet and only in rare cases exceeds 300 feet. The mean flow of water in the bigger rivers amounts to about 10,000 cubic feet per second at the mouth. Kaplan turbines have been used for heads up to 110 feet; for greater heads, Francis turbines are used.

When planning and constructing a power station, all efforts are made to utilize the head of the falls and rapids of the river in the best possible way and to obtain the lowest possible annual costs. In order to find the most economical position for the dam, a preliminary survey is first made in which are calculated the cost of constructing the dam, headrace, and tailrace for different alternatives. In order to make the final choice between the various alternatives, annual costs for the plant are compared.

The progress in the technique of digging and blasting has often made it economically possible to concentrate the head of falls and long rapids in a single power station. On account of the damages on cultivated areas and settlements or the fact that the valleys of the Swedish rivers are comparatively broad, a high dam often will be uneconomical. Normally, therefore, the concentration of the greater part of the head must be done by means of tunnels, canals, and river bed clearance.

If the ground is composed of good rock and its surface is on a sufficiently high elevation, the most economical solution for the power plant often is to place the machine station underground and to construct the tailrace either partially or wholly as a rock tunnel. The penstocks are, in that case, placed vertically. An example of a Swedish underground station is shown in Figure 1.

If a surface station was to be built in rocky ground instead of an underground station, it would be necessary either to maintain the turbines as in the underground station, but this time in deep shafts, and place the generator hall only at the ground surface, or to construct the station with sloping tubes and the power station on the ground. A station with deep turbine pits and long driving shafts is usually more expensive to construct than an underground station in rock and is, in addition, less advantageous from the operational point of view. A station with long penstocks makes regulation of the turbines more difficult, and the additional cost for the extended length of the penstocks on account of a sloped location is usually considerably greater than the saving which results from having a shorter discharge tunnel. Headrace tunnels in rock require lining and tailrace tunnels do not. In comparing underground and surface power stations, it must be remembered that maintainance and depreciation costs for tunnels and rock rooms are expected to be lower than for corresponding parts of a surface station where concrete has to be used.

When the machine hall is located below the ground, the control room is usually also placed underground. Despite the increased cost, the transformers are then usually placed in rock rooms so that all the vital parts of the installation are equally well protected from air attack.

The attendance of an underground station does not differ essentially from that of a surface station. No direct disadvantage in the operation of an underground station can be pointed out in comparison with a surface station.

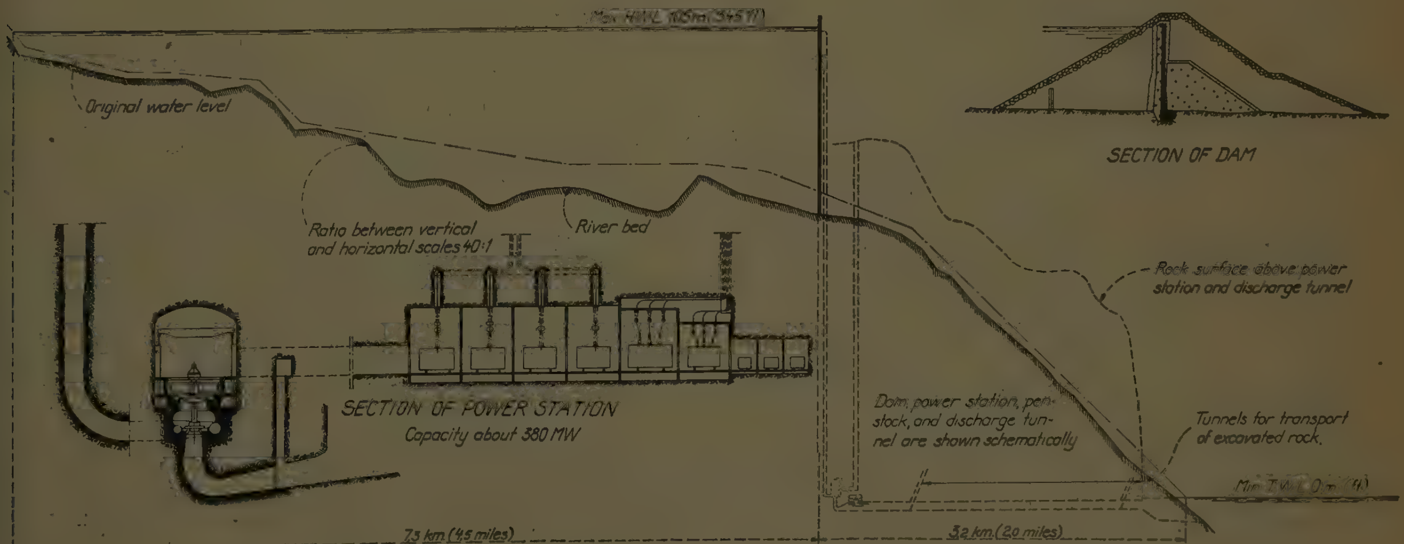
Max HWL 105m (345 ft)
Original water level
Ratio between vertical and horizontal scales 40:1
River bed
SECTION OF DAM
Rock surface above power station and discharge tunnel
SECTION OF POWER STATION
Capacity about 380 MW
Dam, power station, penstock, and discharge tunnel are shown schematically
Tunnels for transport of excavated rock.
Min TWL 0m (0 ft)
73 km (45 miles)
32 km (20 miles)

Figure 1. Underground station with comparatively high rockfill dam

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Digest of paper 50-149, "Underground Hydroelectric Power Stations in Sweden," recommended by the AIEE Committee on Power Generation and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Perception of Electric Currents

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The results of tests of sensations of 150 people experiencing increasing currents and frequencies are recorded in this article. In most cases the current required for perception increased with increasing frequency, and between 1,000 and 100,000 cycles the current was nearly proportional to the frequency.

ELECTRIC CURRENTS which are just perceptible are important, as it is essential that the user not get the sensation of electric shock when using electric appliances, hand tools, or other electric equipment.[1] Shocks produced by currents near the threshold of perception are generally considered annoying rather than dangerous; however, when such shocks are unexpected, they are startling, and serious accident may result as a secondary effect. For example, an unexpected electric shock, far too feeble to cause injury due to direct effects of the electric current, might produce a sudden movement and cause subsequent contact with a dangerous mechanism, or it might cause loss of balance with an ensuing fall which might cause painful injury.

The investigations reported here were undertaken to expand the knowledge of the effects of electric current on the human body by observing the phenomena of perception under several contact conditions for direct current and for sine-wave alternating currents from 60 to 200,000 cycles per second. The experiments were conducted in the electrical engineering laboratories of the University of California at Berkeley, during the academic years 1940 and 1948–49. Four women and 143 men participated in the investigations.

Only subjects apparently in good physical condition were used in the study, and only those parts of the skin which were free from cuts and abrasions were subjected to quantitative tests. Moist contacts were used in the investigation to minimize the range of contact resistances and to permit the use of low voltages for safety. As a result of the low voltages employed only minute sparks were produced when the subject interrupted the current. Care was exercised to avoid causing burns at the points of contact with the body, and although burns are extremely important, of necessity this subject was not investigated. It is entirely possible that arcs might occur with commercial apparatus at the higher perception current levels corresponding to the higher frequencies, and these arcs might cause painful burns, especially if sustained for a considerable period of time.

The subject sat in a relaxed position in a chair so located that he was facing away from the test equipment. After the subject was prepared for the test, he was told that the operator would slowly increase the current, and he was asked to report when the first sensation was observed. When the subject perceived the current, the increase in current was stopped, and the magnitude was noted. The current was then decreased to zero in preparation for another run. One or two trial runs allowed the subject to become acquainted with the testing procedure and the sensations resulting from the frequency being investigated. Three or four determinations of the minimum current perceived with slowly increasing current were then made and the values were recorded. The results of the trial runs were not recorded as the purpose of these runs was to acquaint the subject with the sensations involved at each frequency. This technique yielded a conservative value, as the current required for perception in the first determination for each subject at any frequency was generally somewhat higher than subsequent values.

Throughout this investigation an individual's threshold of perception at a given frequency is taken as the mean value of current just causing sensation when using a subthreshold approach. The threshold of perception for a group is taken as the mean value of the group. The current likely not to be perceived is taken as that value of current which is detectable by only 0.5 per cent of the group, and the upper limit of perception current is taken as that current perceived by 99.5 per cent of the group.

Aside from physiological factors which were beyond the control of the investigators, five factors are important in determining the current which can just be perceived. These are: point of contact, type of contact, rate of increase of current, frequency, and wave form.

Inasmuch as the point of contact with the skin has considerable effect on the level of the current required for perception, it is obvious that a great many different perception thresholds could be investigated. Considerable thought was given to this phase of the problem, and it was decided to concentrate on the hand and fingertips, since contact with the hands is responsible for many of the complaints caused by electric currents near the perception threshold. Preliminary tests were made on the tongue, and although the results of this threshold are of minor practical importance, comparison with results obtained on hands emphasizes the range of values for different points on the body.

Three types of contacts were used. These consisted of holding, touching, and tapping test electrodes. In the holding contact tests smooth wire or wires were held in the palms of the hands or placed lightly on the tongue. For the touching contact tests, the middle finger was placed lightly

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This is the first of a series of articles on safety.

Essentially full text of paper 50-184, "Effect of Frequency on Perception Currents," recommended by the AIEE Committee on Safety and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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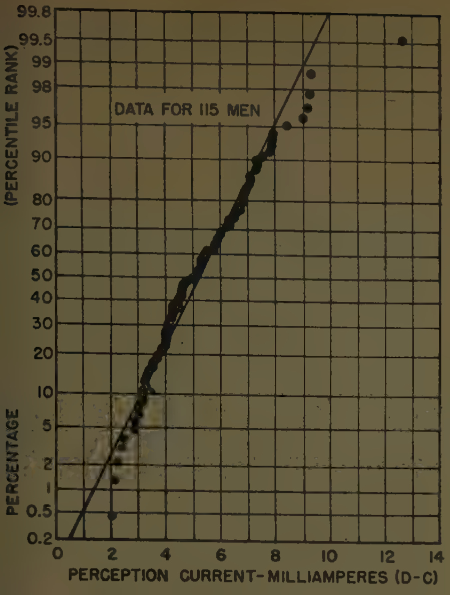

Figure 1. D-c perception distribution curve for hands holding Number 7 copper wires

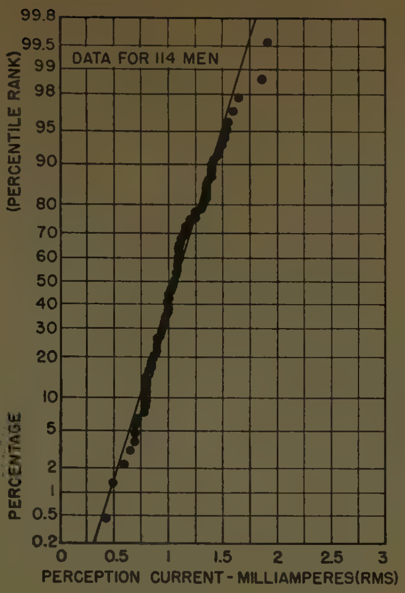

Figure 2. 60-cycle perception current distribution curve for hands holding Number 7 copper wires

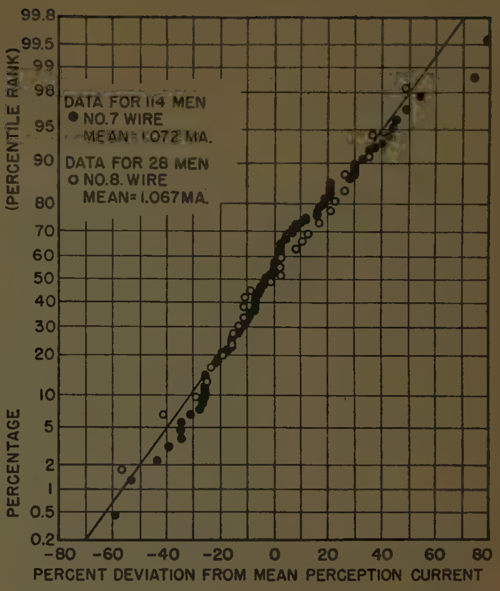

Figure 3. 60-cycle deviation curve for hands holding Number 7 and Number 8 copper-wire electrodes

on a polished flat copper plate. In the tapping contact test, the middle finger tapped the copper plate at a rate of once to twice a second. Two identical electrodes were used in the first series of tests. In the second series the circuit was completed by an indifferent electrode, consisting of a flexible lead strip wrapped with gauze soaked in salt solution which was clamped around the upper arm.

The magnitude of the current, accommodation effects, and the effect of frequency and wave form on perception will be discussed later in the article. In the first series tests were made on 115 men, using direct current obtained from batteries and commercial 60-cycle alternating current. For subsequent tests, made on 28 men and four women, the a-c power supply consisted of a Hewlett-Packard Model *200C* audio-frequency oscillator and a power amplifier. The output was continuously monitored with a Dumont Model *208B* cathode-ray oscilloscope and care was exercised to maintain sinusoidal wave shapes.

GENERAL OBSERVATIONS

In addition to the numerical data, certain phenomena were observed relative to the sensations caused by the passage of electric current through the hands. These observations are of assistance in interpreting the quantitative results of the investigation and will be discussed prior to presentation of the experimental results.

At the outset it was planned to establish the perception current on the hands with both gradually increasing and decreasing currents in anticipation that this procedure would yield an accurate determination of the threshold of perception for a given frequency. However, it was found that when the current was adjusted to a value slightly greater than an individual's threshold of perception and was then gradually decreased, erratic values were obtained and the subject reported difficulty in determining when the sensation actually ceased. A particular individual might report that he thought the sensation had ceased at current values varying from slightly above his perception value for gradually increasing current to a current of approximately one-half of this magnitude. Results of the tests performed with decreasing current were so variable in comparison with the close agreement of the individual's reponse at a particular frequency with increasing current that little information appears to be gained from this type of test. It was hoped that some observations attributable to after-effects, or to accommodation processes, might be explained using the intended technique, but the great variation in the reported values prohibits the drawing of worth-while conclusions. The original plan was abandoned, and except for a few preliminary tests a subthreshold approach was used throughout the investigations.

For tests using frequencies of more than approximately 30,000 cycles, it was observed that the rate at which the current was increased had an appreciable effect on the current level at which perception occurred; in contrast, the perception current at lower frequencies appeared to be independent of the rate at which the current was increased. For higher frequencies, as the current was increased at faster rates the subject reported the presence of sensations at successively lower levels of current. As a result, an attempt was made to approach the higher frequency thresholds at a rate of current increase of approximately three to six milliamperes per second. Varying the rate at which the current was increased to roughly 75 per cent of the threshold value failed to produce appreciable variations in the threshold provided the remainder of the approach was made at the established rate; consequently, this procedure was followed to save time and reduce fatigue.

The phenomenon of accommodation at the higher frequencies again manifested itself in the touching and tapping contact tests. In this instance, the value of current just perceived when tapping the copper plate was considerably less than the current required for perception when touching the plate with gradually increasing current. When the energized plate was touched and contact was maintained many subjects reported an initial sensation that faded away in several seconds. The time required for the sensation to fade away seemed to be a function of the intensity of the initial sensation. Quantitative determination of this interval was not attempted because of the difficulty of determining the moment that sensation ceased.

Several subjects reported that they were able to draw slight sparks from the copper plate when the contact was broken during the tapping contact test at the higher frequencies. The minuteness of the pin-point burns caused by these sparks, which were not visible in a normally lighted room, is attributed to the fact that the voltage used in these tests was sufficient to maintain a spark for only a very short period of time as the finger moved away from the electrode. The open-circuit voltages employed varied between about 20 and 100 volts; maximum current was about 112 milliamperes.

Several times during the holding contact investigations the subjects reported a definite sensation when they released the electrodes while a current slightly below the perception level was flowing. The same phenomenon was reported by several subjects when the circuit was interrupted by the operator. However, the phenomenon did not occur with sufficient regularity to permit determination of its cause.

Included in the following paragraphs are generalized comments on the sensations for currents about 25 to 50 per cent above the perception value.

As would be expected, the sensations caused by direct current are different from those occurring when alternating current is applied. Except when the current is changed suddenly, muscular contractions are absent. If the surface of the skin is intact, the first sensations are those of slight warmth in the palm or in the wrist, and these sensations are quite difficult to detect. If the surface of the skin has minor defects, sharp piercing sensations are produced with very low currents.

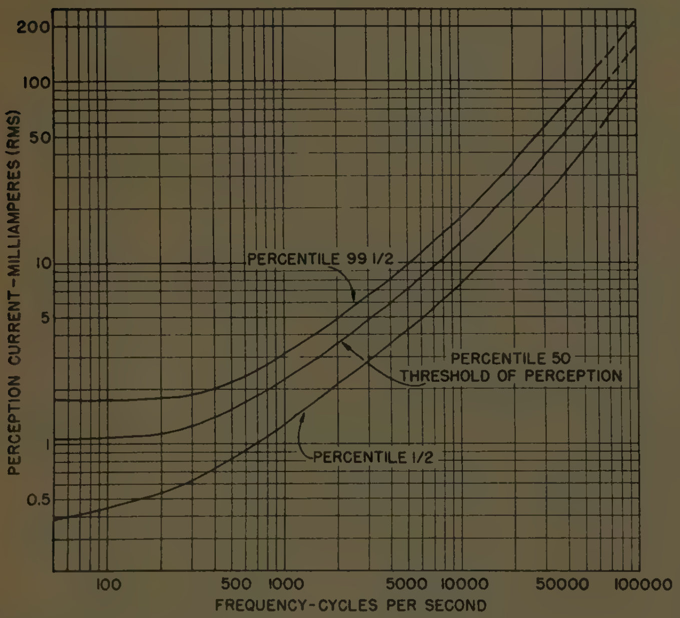

Figure 4. Effect of frequency on perception current with the hand holding Number 8 copper wire

The outstanding feature of the sensations in the power frequency range is the sharpness of the sensation when the perception current is exceeded. This sensation is variously described as a tingling or pricking sensation at the point of contact. Many of the subjects also observed this sensation under the indifferent electrode. This effect was not reported at frequencies in excess of 1,000 cycles. The presence of sensation at the indifferent electrode was attributed to the presence of small imperfections in the surface of the skin under this electrode, and was probably due to high current densities at tender spots, but no explanation is offered for its disappearance at the higher frequencies. At very low frequencies (5 to 20 cycles) the muscles of some of the subjects were observed to follow the alternations of the current wave form; however insufficient data were taken to establish the threshold at these frequencies.

As the frequency was increased, the intensity of sensation caused by currents slightly greater than the perception value decreased. For frequencies between 1,000 and 10,000 cycles, the subjects commented that the sensation was smoother, softer, and less piercing than that caused by 60-cycle currents, and that it seemed to spread from the area in immediate contact with the test electrode to a greater part of the hand. Several subjects stated that currents having frequencies near 10,000 cycles caused a sensation similar to that observed when the hand "goes to sleep."

Currents of frequencies between 30,000 and 90,000 cycles were reported to give an increasing spread of sensation away from the test electrode, and to cause a sensation of drawing of the skin or of a pressure on the hand. As the frequency increased, the sensation was less intense.

The touching and tapping contact tests using frequencies between 100,000 and 200,000 cycles brought forth the opinion from all subjects that the sensation caused by the higher frequencies was one of heat rather than of the muscle stimulation noted at the lower frequencies. After the subject had reported this change in sensation, an attempt was made to determine the frequency at which the change occurred. A majority of the subjects first became aware of the change in sensation at approximately 100,000 cycles. Several subjects noticed it at about 150,000 cycles, and two subjects failed to observe any material change in sensation until a frequency of 200,000 cycles had been attained. Apparently the change in sensation is a definite change, rather than the gradual changes experienced at frequencies below 100,000 cycles. The sensation of heating at frequencies of 100,000 cycles was also reported by A. E. Kennelly and E. F. W. Alexanderson in their studies on this subject.[2]

The current required for perception at frequencies of 100,000 or more cycles was less dependent upon the rate of increase of the current than at frequencies between 30,000 and 90,000 cycles. A second phenomenon was observed that indicates the difference in the nature of perception current in the higher frequency range. When currents of 100,000 or more cycles were adjusted to values slightly less than the perception values and maintained constant, perception was reported after an interval of several seconds. In contrast, for frequencies less than 100,000 cycles, currents of slightly less than the perception value were not perceived after an interval of several minutes.

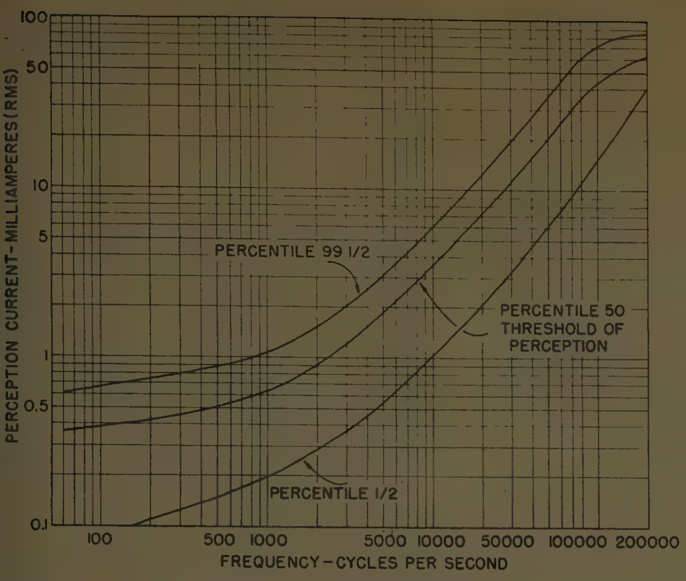

Figure 5. **Effect of frequency on perception current with the middle finger touching a copper block**

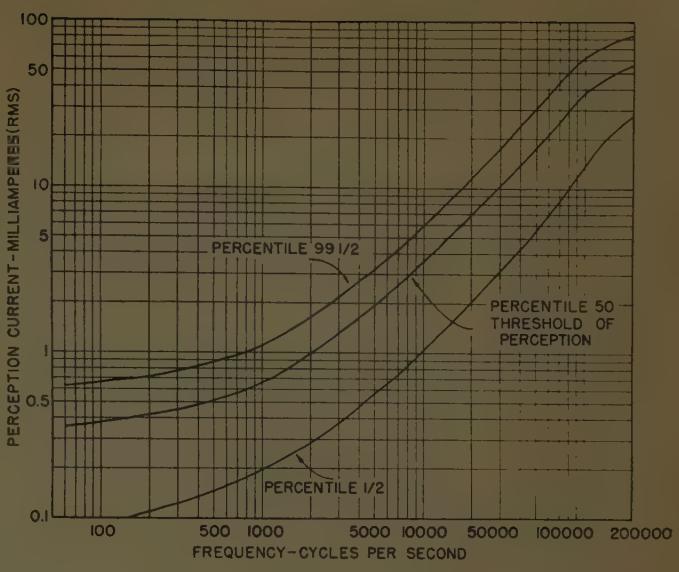

Figure 6. **Effect of frequency on perception current with the middle finger tapping a copper block**

These changes in perception phenomena with frequency are also apparent from the experimental data. It was observed in this investigation, and also in other investigations involving the response to electric stimulation,[3–5] that regardless of the current required to initiate a given response, as long as the phemonena are similar, the deviation curves derived from the experimental data will have nearly identical slopes. It was noted that the deviation curves for the touching and tapping contact tests have the same slopes for a frequency range from 1,000 to 70,000 cycles. Similarly, the holding contact deviation curves have the same slope for frequencies between 1,000 and 60,000 cycles. At very low frequencies the phenomena are more complicated as the muscles tend to follow the current alternations, and the deviation curves have different slopes. At the very high frequencies stimulation of the heat-sensory mechanisms predominate, and again the slopes are different. The transition is completed between 100,000 and 200,000 cycles, and it would seem reasonable to expect that deviation curves for frequencies which are higher than 200,000 cycles might have slopes similar to those which were obtained for the 200,000-cycle tests.

PERCEPTION ON THE TONGUE

The current which can just be perceived with two contacts placed lightly on the tongue was determined using direct current and 60-cycle alternating current. The electrodes consisted of two Number 18 wires, one inch long, separated by means of a bakelite separator. Platinum wire was used to reduce local galvanic effects. The electrodes were sterilized, washed with water, and dried between tests on different subjects. During the test, the subject held the electrodes lightly on the tip of his tongue and indicated when he first observed sensation as the current was gradually increased. There was considerable variation between successive tests on the same individual, and the average of several trials was taken as the perception value for the individual. The sensation might be described as one of taste and is distinctly different from the characteristic tingling or warmth usually associated with electric stimulation applied to other parts of the body.

The results using direct current for 115 men were: 44.7 microamperes mean, 16 microamperes median, 0.6 microampere minimum, and 783 microamperes maximum. Results for these men using 60-cycle alternating current were: 45.3 microamperes mean, 30 microamperes median, 4 microamperes minimum, and 315 microamperes maximum. The threshold of perception on the tongue is taken as the mean value and is approximately 45 microamperes for either direct current or 60-cycle alternating current.

It is apparent from these data, and also from a detailed statistical study, that the response did not follow a normal distribution but was skewed positively (toward the higher values). These findings are exceptional as the physiological response of a large group usually follows a normal distribution.

A tentative explanation for the skewed response is that the small separation of the electrodes permitted the saliva on the surface of the tongue to shunt part of the current from penetrating to the nerve endings deeper in the tissues. Possibly the response might have more nearly approached a normal distribution had one electrode been placed on the tongue, with the circuit completed by an indifferent electrode located at some remote point, such as an electrode held in the hand.

PERCEPTION OF THE HAND

Perception currents for 115 men with electrodes held lightly in the palms of the hands were determined using direct current and commercial 60-cycle alternating current. The results are given in Figures 1 and 2 respectively. The hands were moistened with a saturated salt-water solution (NaCl) to reduce and minimize variations in contact resistances and to permit the use of low voltages for safety. The subjects sat relaxed in a chair and rested the palm of each hand on smooth Number 7 copper wires which were supported by the arms of the chair. The current was then

Table I. Effect of Frequency on Perception Current

Statistical Data for 28 Men

	Holding No. 8 Wire			Touching Contact			Tapping Contact		
Frequency, Cps	Subjects Used	Percentile 50 Ma	Deviation at $^1/_2$ and $99^1/_2\%$, in Per Cent	Subjects Used	Percentile 50 Ma	Deviation at $^1/_2$ and $99^1/_2\%$, in Per Cent	Subjects Used	Percentile 50 Ma	Deviation at $^1/_2$ and $99^1/_2\%$, in Per Cent
60	28	1.067	63	25	0.36	75	25	0.36	75
300	25	1.234	50						
1,000	25	2.299	40	24	0.65	70	24	0.65	70
3,000	25	4.828	40						
10,000	25	12.13	40	25	3.57	70	25	3.51	70
30,000	25	37.14	40						
40,000	25	53.67	40	24	15.96	70	24	14.04	70
50,000	25	70.10	40						
60,000	25	85.49	40						
70,000	19	101.5*		25	32.20	70	23	25.03	70
100,000				25	43.80	65	25	37.84	65
150,000				25	55.40	50	25	48.51	55
200,000				25	63.63	35	25	55.76	50

* Corrected for size of sample.

gradually increased, and several trials were made to determine the smallest current that could be felt.

The results for 115 men using direct current were: 5.2 milliamperes mean, 5.0 milliamperes median, 2.1 milliamperes minimum, and 12.6 milliamperes maximum. The results using 60-cycle alternating currents were: 1.072 milliamperes mean, 1.05 milliamperes median, 0.44 milliampere minimum, and 1.92 milliamperes maximum. It is apparent from Figures 1 and 2 that the response closely approximated a normal distribution. The mean and median values are substantially identical, and the mean value is considered to be the threshold. Therefore, the threshold of perception with electrodes held in the hand for direct current is taken as 5.2 milliamperes and 1.07 milliamperes for 60-cycle alternating current. The current likely not to be perceived is taken as the value corresponding to the one-half percentile. For direct durrent this is approximately 1.0 milliampere, and for 60-cycle alternating current 0.4 milliampere.

Deviation curves are helpful in analyzing the response to electric stimuli, and they were utilized in this investigation in a manner similar to that employed in previous papers in this field.[3–5] The solid dots of Figure 3 represent experimental points for the 60-cycle test with both hands holding the Number 7 copper-wire electrodes. The points are plotted in ascending order to show percentile rank as a function of the per cent deviation from 1.072 milliamperes the mean of the group. The war period intervened between the completion of the 60-cycle test on the 115 men and similar tests recently completed on an entirely new group of 28 men.[6] Data for this new group are shown by the open dots of Figure 3. Since these data are plotted on probability paper, the straight line of best fit was drawn by eye through the 50th percentile and zero deviation point to establish the deviation curve.

In the latter tests, the 28 subjects grasped a polished Number 8 copper-wire electrode in the palm of the hand with light pressure and in a steadfast manner. The circuit was completed by an indifferent electrode which was clamped around the upper arm. The indifferent electrode consisted of a $1^1/_2$-inch lead strip wrapped with gauze. The strip was sufficiently long nearly to encircle the subject's upper arm, and the arm band was moistened with a saturated salt-water solution to insure good electrical contact. To reduce the electric shock hazard, either the left or right but always the same hand and arm were used to prevent the current from passing across the body. It was found that there was less fatigue when the arm through which the current was passed was allowed to hang loosely at the side, rather than when the arm was allowed to rest upon a surface of a table or on the arm of a chair. For this reason the subject was instructed to let his arm hang free at his side during the tests. Preliminary investigation revealed no significant difference between the perception current obtained when the left or the right hand was used to hold the test electrode; however, the presence of minor cuts on a hand or fingers decreased the amount of current required for perception, and the choice of whether the left or right hand was used depended upon the condition of the skin. The threshold or mean value for this group was 1.067 milliamperes, which compares favorably with the value obtained on the larger group eight years before.

The fact that a single line drawn on probability paper accurately represents the response for these two sets of data is significant because the data were obtained from different groups of subjects, at different times, and using different current pathways through the body. It is evident that the perception of electric current on the hands follows a normal distribution, and that results obtained from groups consisting of approximately 25 subjects are sufficient to permit valid conclusions. Furthermore, it is believed that a sufficient number was used to permit valid statistical predictions, not only for the particular group tested, but also for a normal cross section of the adult male population of the country. The probability of a given current being perceptible is arbitrary, and the one-half percentile value was selected as a reasonable criterion for establishing the level of

Table II. Experimental Data for 28 Men and 4 Women Holding Number 8 Wire Electrode

Frequency, Cps	Men Minimum Current, Ma	Men Mean Current, Ma	Men Maximum Current, Ma	Women Minimum Current, Ma	Women Mean Current, Ma	Women Maximum Current, Ma
60	0.47	1.067	1.60	0.85	1.18	1.57
300	0.82	1.234	1.78	1.20	1.27	1.47
1,000	1.67	2.299	2.86	1.70	2.06	2.32
3,000	3.70	4.828	6.55	3.33	4.37	5.05
10,000	8.60	12.13	15.2	9.65	10.96	12.5
30,000	27.1	37.14	48,5	27.9	30.4	31.8
40,000	36.8	53.67	76.3	35.8	42.0	46.5
50,000	48.4	70.10	89.5	52.6	55.0	58.6
60,000	65.0	85.49	112.0	64.6	67.7	70.0
70,000	74.2	94.98	107.8	77.5	80.5	85.1
80,000	89.5	100.8[1]	106.5	91.0	94.7	100.0
90,000	101.5	104.0[2]	106.4	100.8	102.7	105.7

[1] Data for 6 men.

[2] Data for 2 men.

current not likely to be perceived. The current required for other probabilities may be obtained by using the following equation:

Current = (Mean of Group) (1 ± Deviation from Mean corresponding to Percentile Rank Desired).

Perception current tests were made for three different contact conditions over a frequency range from 60 to 200,000 cycles. The contact conditions consisted of: holding copper wires, resting the tip of the middle finger on a small copper plate, and tapping that finger on the copper plate.

The electrodes used for the holding tests consisted of $4^1/_2$-inch lengths of polished Number 8 and Number 4 copper wires. For the touching contact tests, the tip of the middle finger was allowed to rest upon the copper plate without the exertion of pressure other than that caused by the weight of the finger. In the tapping contact tests, the finger was raised from the plate and then allowed to fall and make contact at a rate of one to two times a second. The test electrode for the touching and tapping tests consisted of a polished copper plate $2^1/_2$ inches by $1^1/_2$ inches by 3/16 inch, which was set on an insulated base and placed on a table in front of the subject.

Deviation curves similar to Figure 3 were established for the holding, touching, and tapping contact tests for the various frequencies. Space limitations prohibit inclusion of deviation curves for each frequency and contact condition. However, the per cent deviation for any percentile rank can be derived from the statistical data given in Table I. The $99^1/_2$, 50, and 1/2 percentile points obtained from these deviation curves were entered in Figures 4, 5, and 6, and smooth curves were drawn to show the effects of frequency on perception current for the three contact conditions. The middle curve, which is based on the 50th percentile values, establishes the threshold of perception for the given conditions. The lower curve represents the current likely not to be perceived, while the $99^1/_2$ percentile curve defines the upper limit of perception current.

For the holding contact tests only the most susceptible subjects were able to perceive currents of frequencies in excess of 60,000 cycles within equipment limitations. However, 19 of the group tested at 60,000 cycles reported perception at 70,000 cycles, and the mean value for the group was corrected according to the following equation:

$$\text{Corrected Mean of Sample} = \frac{\text{Mean 60,000-Cycle Perception Current for 25 Men}}{\text{Mean 60,000-Cycle Perception Current for 19 Men}} \times \text{Mean 70,000-Cycle Perception Current for 19 Men}$$

The number of subjects reporting perception for frequencies in excess of 70,000 cycles was too small to justify statistical analysis; however, it is believed that the similarity of the shapes of the curves of Figures 4, 5, and 6 justify extrapolating the holding contact curves to 100,000 cycles. Since the nature of the sensation underwent a noticeable change beginning at about 100,000 cycles the extrapolation was not carried above this frequency.

Table IV. Experimental Data Tabulated According to Age of Subject

Frequency, Cps	Type of Contact	Subjects 30 Years and Less: Number Used	Subjects 30 Years and Less: Mean Ma	Subjects 31 Years and Over: Number Used	Subjects 31 Years and Over: Mean Ma
60	Holding No. 8 wire	19	0.99	6	1.34
10,000	Holding No. 8 wire	19	11.60	6	13.80
60	Touching	18	0.34	7	0.43
10,000	Touching	18	3.10	7	4.76
200,000	Touching	18	60.25	7	72.33
60	Tapping	18	0.32	7	0.41
10,000	Tapping	18	3.08	7	4.63
200,000	Tapping	18	53.1	7	62.61

Experimental results obtained from holding-contact tests for the 28 men and four women are given in Table II. Although tests based on only four subjects are not sufficient to warrant more than passing comment, it is significant that the extreme values for the women generally fell within the range of currents perceived by the men. The differences in the mean values for men and women at any frequency are inconsequential.

A series of tests were made on ten male subjects using Number 8 and Number 4 copper-wire electrodes held in the palm of the hand to investigate the effects of contact area. The results of these tests, which are given in Table III, fail to show a significant difference in the current required for perception as a function of electrode diameter. Although the ratio of surface areas of the two electrodes was 1.59, the amount of the surface of each electrode in actual contact with the skin may have been nearly the same due to the folding of the skin around the test electrode. The results reported by H. A. Carter and J. S. Coulter[7] indicate that the current required for perception increases as the contact area is increased, but not in direct proportion to the increase in area.

An attempt was also made to compare the current required for perception according to different physical characteristics. Inconclusive results were obtained when the subjects were grouped according to complexion and general build (heavy, medium, or slight); however, mean values of perception current for the men segregated into two age groups suggest that the current required for perception is somewhat dependent on age. The results of holding, touching, and tapping contact tests are given in Table IV. A greater number of subjects would be required to definitely establish the relationship between perception current and age.

Although the effects of wave shape were not investigated per se, it is

Table III. Experimental Data for 10 Men Holding Number 8 and Number 4 Wire Electrodes

Frequency, Cps	No. 8 Wire Electrode: Minimum Current, Ma	No. 8 Wire Electrode: Mean Current, Ma	No. 8 Wire Electrode: Maximum Current, Ma	No. 4 Wire Electrode: Minimum Current, Ma	No. 4 Wire Electrode: Mean Current, Ma	No. 4 Wire Electrode: Maximum Current, Ma	Ratio of Mean Values No. 4/No. 8
60	0.59	1.046	1.38	0.53	1.119	1.52	1.07
1,000	1.29	2.036	2.70	1.25	2.160	3.15	1.06
30,000	21.6	30.03	46.1	21.3	30.90	49.5	1.03
60,000	49.5	65.67	97.4	49.2	69.10	99.0	1.05

believed that the factors controlling let-go currents[3,4] would apply also to perception currents. There is strong evidence to support the conclusion that the crest and not the rms value is the critical factor in stimulation with low-frequency sine waves. The decrease in sensitivity with increasing frequency suggests that the effect on higher harmonics or repetitive pulses superimposed on low-frequency alternating current, would have less and less effect as the frequency of the superimposed current was increased. Above 100 to 200 kc it might be expected that the sensation of heat would be largely masked out by the muscular stimulation of the lower frequency components.

Acknowledgement is given Spencer H. Robley who, in 1940, obtained the experimental data for the group of 115 subjects. He was senior student in electrica engineering, University of California, Berkeley, at the time the study was made.

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Audible Noise of Power Transformers

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The control of noise levels of power transformers without seriously affecting other important characteristics of the transformers is an important challenge to manufacturers. Here are discussed some of the sources and characteristics of transformer noise and the methods used by manufacturers to overcome these noises.

TRENDS in power-system design require installations of large power transformers in thickly populated areas. These trends have been brought about by increasing capacities of existing stations and by transforming power closer to the ultimate customer than has been done in the past.[1] As a result, power-transformer manufacturers have been asked to build low-noise-level designs for these installations. Simultaneous with these new requirements being placed on them, manufacturers have been developing new materials, processes, and material applications; and to advance the art, certain of these improvements are being incorporated in designs. The manufacturer then finds himself faced with the problem of designing for low noise levels and, at the same time, improving his product in quality, cost, and dependability. The way in which these two parts of the problem are related will be shown in this article.

SOURCES OF NOISE

TRANSFORMERS are becoming more complex because of their requirements, and no longer can the only source of transformer noise be considered magnetostriction. Even though magnetostriction is still recognized as one important driving source of audio noise, there are other sources, such as resonant parts of structures, vibrations at core gaps and joints, vibrations caused by interaction between core and coils, and vibrations of the coil conductors carrying current, which may result in noise generation or aid in noise transmission.

Magnetostriction. Magnetostriction may be defined as the change of dimensions of a magnetic material under magnetic stimulus. This is the only source of vibration in the core that is a property of the material, and true evaluation of this property can be obtained only with a d-c stimulus. D-c magnetostriction measurements may be made,[2] and results are similar to d-c magnetization data[2,3] in that a singly valued relation between magnetostriction and flux density is obtained on the initial magnetization of the sample. A loop is obtained if the flux density is increased and then decreased. Magnetostrictive characteristics are dependent upon the surface of the sample, the strain in the sample, and the heat treatment of the sample. Chemical composition of the steel also affects magnetostriction. Variation of d-c magnetostriction of transformer core steel with flux density generally follows a concave curve of three different types: *A*, *B*, and *C* of Figure 1, or, much less often, a convex curve *D* of Figure 1. Curves of Figure 1 are for the initial magnetization of the sample. If the flux density is varied through positive and negative values of flux, starting with an initially unmagnetized sample, the single-valued curve goes into a loop as shown in Figure 2. Both the single-valued curves and the loop show a nonlinear rela-

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tion between magnetostriction and flux density. This nonlinearity requires harmonics in magnetostriction if flux density is varied sinusoidally.

In making a-c magnetostriction tests, factors other than the material in the sample may affect the shape of the a-c magnetostriction-flux density curve. Measurements of a-c magnetostriction have been made,[4] and a-c loops are similar to the d-c loop of Figure 2. If, however, the peak a-c flux density be increased to where it approaches saturation, the a-c loop becomes very much distorted as shown in Figure 3. Again, vibration harmonics are generated; and since small sections of core laminations in joint regions are at very high flux densities during parts of the flux cycle, high-frequency components of vibration will exist around these sections.

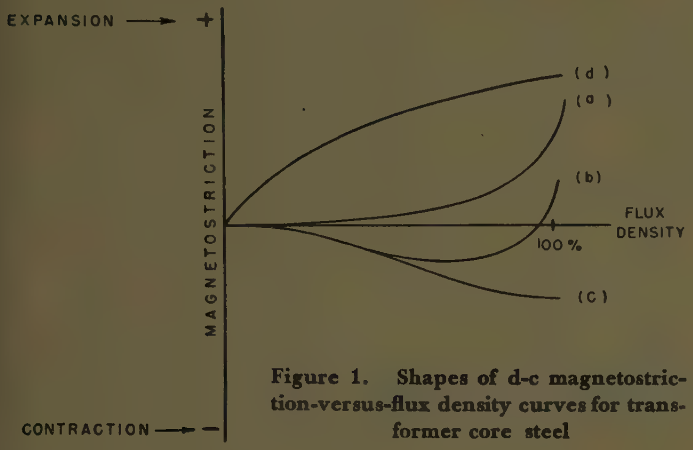


Figure 1. Shapes of d-c magnetostriction-versus-flux density curves for transformer core steel

Not only is the magnitude of magnetostriction important, but the shape of the curve or loop is equally as important because of the harmonic phenomena involved. Even though one core material may have less magnetostriction magnitude than a second material, it may cause more effective noise emission than the second material unless frequency distribution is confined to the fundamental and low harmonics.

Volume magnetostriction is another type of magnetostriction, but up to the present time, it is believed that it plays a negligible part in causing audio noise. In this type of magnetostriction, change in volume is considered instead of change in a linear dimension.

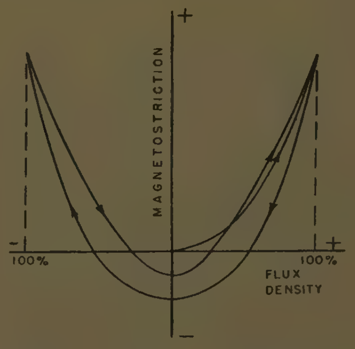
Gaps and Joints. Cores of power transformers are usually built by stacking many thin laminations into a structure. Necessarily, these laminations have junctions, joints, and gaps of one type or another through which flux must pass. Most such joints have overlapping regions in which the flux is divided between the parallel iron and air paths. Division of flux between the paths varies throughout the cycle because of the variable iron permeability. Also, flux distribution in the corner sections of plate-type cores is nonuniform.[5] Across these gaps or joints in the core exists a force at each instant during the cycle that varies as the square of the instantaneous flux density. These forces tend to vibrate the leg and yoke sections of the core, thus becoming a source of noise.

If these regions had only fundamental flux in them, only a vibration and noise frequency of twice the core-excitation frequency would be obtained. That is, if only 60-cycle, sinusoidal flux were in the joint region, only 120-cycle vibrations would exist. However, with flux distortion and variable permeability in the joint regions, harmonics of the vibration and noise fundamental are generated, and this in turn is emitted from the transformer, as will be shown later in this article.

Resonating Parts. Almost all materials which are built into a transformer have, either themselves or as a structure, mass and spring characteristics. This is true for the core tank, radiator tubes, junction boxes, control cabinets, and so forth. Also, to some extent, there is a damping component associated with the mass and spring characteristics. Depending upon the geometrical shape, mass, elastic properties, and material of the part or structure being considered, resonant frequencies may be obtained that fall on or near one or several of the component vibration frequencies being supplied by the core. If damping is not sufficient, vibrations of these parts may be large enough to contribute to the transformer noise. Core vibrations have been described by Fahnoe;[6] if resonance of cooling tubes and other components exists, it may be necessary to modify the structure.

Although most of these resonating parts do not in themselves contain sources such as magnetostriction, they may, if not properly designed, be driven by other sources and amplify or easily transmit certain frequencies that would otherwise not be detected so easily. When a transformer has one of its major components, such as a tank wall, in resonance, the slope of the noise level-versus-excitation voltage curve is very small—much under the usual 2- to 3-decibel change in noise for a 10-per cent change in voltage.

Coils and Interaction Between Core and Coils. When current flows in a transformer winding, forces are exerted on the conductors and winding supports. An exaggerated case of such forces occurs whenever a transformer winding is short-circuted. However, at the normal current densities used in power transformer designs, noise emitted by the coils because they are carrying load current is not enough



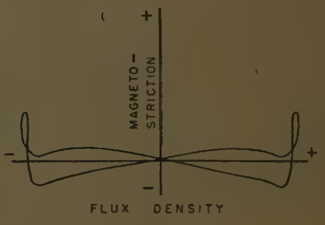


Figure 2 (left). Representative d-c magnetostriction loop of transformer core steel

Figure 3 (right). A-c magnetostriction loop of transformer core steel at peak flux density near saturation

to be appreciable. If the transformer must be designed for exceptionally low noise level, noise due to the coils may then become a source that cannot be neglected.

Similar to the coil noise, noise caused by vibrations due to forces between the coil and core and clamps is negligibly small in normal designs.

Fans and Pumps. Another source of noise which is not related to the transformer proper is the external cooling equipment. This equipment may be fans, pumps, or unit coolers. Usually, this equipment is mounted outside of the transformer tank. Fans are mounted on radiator tubes or headers and, therefore, are a source of noise from one to several feet out from the tank. As will be shown later, the frequency spectra of fans and coolers is quite different from that of the transformer itself.

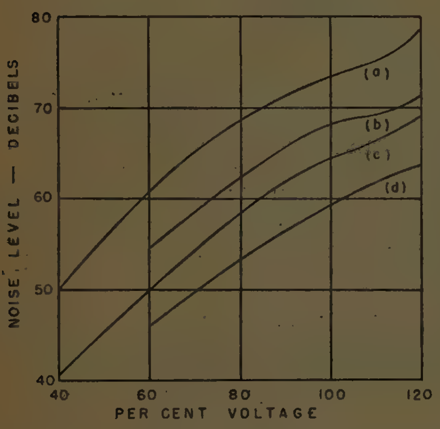


Figure 4 (left). Variation of noise level with excitation for power transformers with cores of different types of steel at 60-cycle excitation

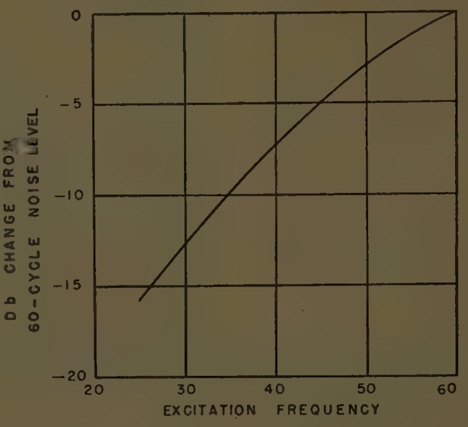


Figure 5 (right). Variation of noise level with excitation frequency for power transformers at frequencies less than 60 cycles

DAMPING MECHANISMS

VIBRATIONS caused by core displacement may be damped in three principal ways: damping in the core structure; damping in structural and metallic parts other than the core and coils; and damping in insulation. Complexity of the conventional power transformer structure makes it very difficult to segregate and evaluate these various types of damping.

In the core steel itself may be damping. Part of this damping will be associated with the loss of energy associated with elastic vibration. In ferromagnetic materials these losses are generally larger than in nonmagnetic materials and may be interpreted in terms of other magnetic phenomena. Part of the damping in steel is due to eddy currents excited by the change of induction of the specimen as a whole, resulting from strain occurring during vibration. Still another type of damping is that caused by local changes of magnetization brought about by strain of vibration and accompanied by irreversible displacement of the boundaries between domains. Damping by interstitial impurities within the iron crystal lattice may be caused by mechanical movement of the sample structure. Damping in core laminations is mostly a problem in metallurgy and physics; and until the various types are evaluated by these fields of science, the transformer design engineer cannot make much use of these characteristics.

Vibrations in structural parts such as clamps, tanks, braces, and so forth, are damped by energy loss related to elastic vibration. Some damping is present in layer and major insulations of the coils. However, all of the damping present in these parts of the transformer are not sufficient to reduce the noise emitted from a noisy core and coil structure to a value low enough to effect appreciable noise reduction. Also, the degree to which this type of damping is effective varies from design to design and is, therefore, not easily predicted and utilized in the design for noise-reduction purposes.

CHARACTERISTICS OF TRANSFORMER NOISE

POWER-TRANSFORMER noise level is dependent upon not only the transformer itself, but also upon conditions imposed upon the transformer. Excitation voltage, magnitude and power factor of load current, and noise sources external to the transformer proper are some of these imposed factors affecting the total emitted noise from a transformer installation.

Variation of Sound Level With Excitation Voltage. Under no-load conditions, the variation of sound level with excitation voltage is dependent upon the type of core and core steel used in the core, as well as the operating flux density for which the transformer was designed. Given a design with a certain core material, the change in sound level for a per cent change in excitation voltage will vary as the excitation voltage is changed. This is shown by Figure 4; curves *A* and *B* are for one type of core using two different steels; curves *C* and *D* are for two different cores of another type but using the same steel as curve *B*. Curves *A* and *B* show a range of decibel-versus-per cent voltage slope from 0.55 to 0.12, depending upon the per cent voltage being considered. The corresponding range for curves *C* and *D* is 0.38 to 0.16. Around 100 per cent voltage, the change in noise level change is between 0.2 and 0.3 decibel for a single per cent change in voltage.

Curves of Figure 4 are for 60-cycle excitation; change in noise level for frequencies lower than 60 cycles is shown by Figure 5. The decrease in noise level with frequency is due to lowering the fundamental noise frequency and all of its harmonics. Necessarily, total noise level would be decreased because of the 40-decibel weighting characteristics specified by the standards for noise meters.[7]

Variation of Sound Level With Load. Present audio noise standards for transformers[8] specify that noise tests be made at 100-per cent excitation voltage with no load on the transformer. In operation of the transformer, the problem still remains to determine what noise level the transformer will have under load if the no-load noise level of the unit is known.

The degree to which load changes noise level is mostly dependent upon the way in which flux of the core is affected by load. Obviously, the type of core, type of windings, and winding arrangement must be considered. Also, in most cases, the noise level of the transformer is determined by the highest flux density in the core if as much as half of the total core steel operates at this high flux density. The problem then reduces to one of determining the variation of core flux density with load.

Basic transformer theory shows that induced voltage of the winding varies with the magnitude and power factor of load. Confining considerations to core-type concentric winding designs, the following facts may be seen.

1. Practically all reactance leakage flux returns through the core because of the high permeability of the core steel as compared with the parallel air path.
2. Addition of this reactance leakage flux to the main core flux will be vectorial; resultant flux in the core will be a function of load magnitude and power factor.
3. Variation of resultant flux in the core will depend upon which winding is being excited and which winding is connected to the load; that is, inside or outside winding as primary or secondary.
4. Resultant core flux will depend upon whether input or output voltage is maintained constant.

It is seen, therefore, that variation of noise level with load is closely related to the transformer design in a manner similar to regulation and must be considered as another characteristic dependent upon other specified characteristics.

Magnitude of noise-level change may be as high as that corresponding to the core flux density being increased by the full reactance flux. For example, if the inside winding be excited, constant output voltage be maintained on the winding, a load of 10-per cent power factor lagging be supplied, and the reactance of the transformer be 10 per cent, change in noise level would be between two and three decibels. This would be an extreme case, and for loads of higher power factors with the inside winding as secondary, no change in noise level would be detected. Change in noise level because of load variation is, therefore, in the order of two to three decibels at the most and may vary all the way down to zero.

Noise Transmission and Reduction. Transmission of vibration and sound from the various sources to final emission to air is through a very complex 3-dimensional network. The simplified block diagram of Figure 6 shows the complexity of the circuit. Sources are shown in heavy blocks and direction of transmission is shown by arrow heads. Three sources are inside the tank and feed through the various components into the tank. On the tank another source, external cooling equipment, is added. From the tank, transmission may be directly to the air or through cooling tubes or heat exchangers and cabinets, and then to air.

Even though transmission of vibration and noise in a transformer is very complicated, the diagram of the transformer noise circuit shown in Figure 6 illustrates the various locations either inside or outside of the tank at which noise suppression measures may be taken.

The core source and external cooling-equipment source are the important ones to be considered. Core noise may be reduced by operating the core at low flux density. Present steels available for transformer cores have magnetic characteristics which make them desirable for operation at flux densities considerably above flux densities required for very low noise levels. Therefore, noise reduction by lowering flux density is very expensive and produces larger, heavier transformers. Another method of reducing core noise would be to eliminate gaps or joint sections. This may be done in small transformers,[9] but in power transformers it is necessary to use cores built up of many laminations instead of a continuously wound core. Still another method to reduce core noise would be to use core steel that has no magnetostriction at any part of the operating flux-density cycle. Such a material, having this and other necessary characteristics, is not available to the transformer manufacturer at the present time.

Introduction of noise barriers inside the transformer tank is the only alternative for appreciably reducing noise transmission through the liquid insulation. This is, in effect, introducing high acoustic impedances in the transmission paths. Such barriers can be built, but they require additional space and weight, both of which should be held to a minimum in a well-balanced, economical design. Such additions, for acoustic reasons only, are necessarily expensive.

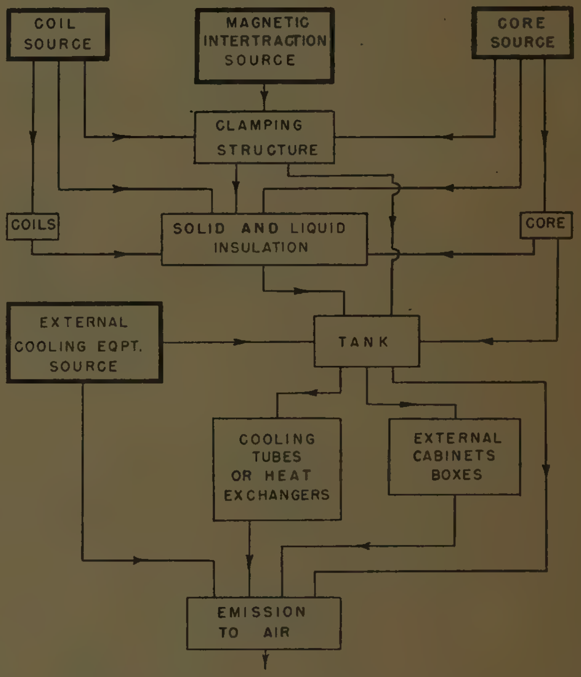

COIL SOURCE
MAGNETIC INTERTRACTION SOURCE
CORE SOURCE
CLAMPING STRUCTURE
COILS
SOLID AND LIQUID INSULATION
CORE
EXTERNAL COOLING EQPT. SOURCE
TANK
COOLING TUBES OR HEAT EXCHANGERS
EXTERNAL CABINETS BOXES
EMISSION TO AIR

Figure 6. Block diagram of transformer noise circuit showing where noise suppression measures may be taken

Fan or cooler noise may be reduced by either using special-design low-noise-level fans which have reduced cooling capacities, or by reducing the operating speeds of standard transformer cooling fans. Reducing fan speed 50 per cent may give noise reductions as high as 30 decibels. To cool transformers with such fans, it is necessary to use many more of them than would be used if they were operated at their standard speeds. Again, this noise reduction is expensive.

Frequencies of Noise. Necessary for noise-reduction studies of power transformers are the frequencies present in emitted transformer noise. Frequency composition of emitted noise varies from position to position around a transformer, but by analyzing several positions around the transformer, the important frequencies with which to be concerned may be determined.

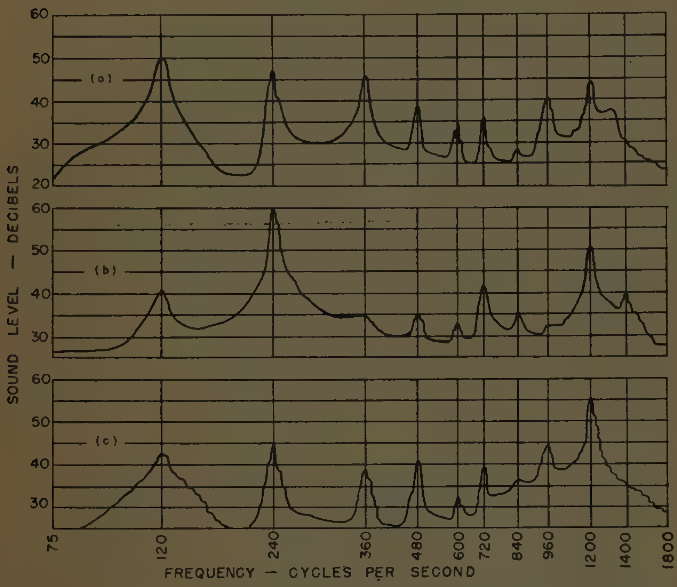


Figure 7. Representative recording of frequencies in transformer noise

Curve	*Predominant Frequency, Cycles*	*Total Measured Noise Level, Decibels*
A	*120*	*55.2*
B	*240*	*59.0*
C	*1,200*	*56.0*

The simplest and most accurate method of obtaining and recording component frequencies is to put the output of the sound-level meter into an analyzer and recorder. The recorded trace then is a plot of sound level in decibels versus frequency, such as that shown in Figure 7. Traces of this figure are for transformers rated 1,000 kva without cooling fans. Peaks of the various component frequencies may be read, and summation of the component frequencies may be checked against the sound-level meter reading. All data in this article were taken with the 40-decibel weighting scale.

In Table I frequencies are given for several transformers to show how frequency composition varies from one transformer to another. From this tabulation it may be seen that, for 60-cycle supply voltage, a range in frequency from 120 to 1,200 cycles must be considered for noise-reduction purposes. Transformer noise is characterized by peaked finite frequencies, while most fan noises have a large component of broad-band noise, as shown in Figure 8. Although peaks may be present in fan noise, a large part of the noise of most transformer cooling fans is contributed by broad-band noise.

DESIGN CHARACTERISTICS AND REQUIREMENTS

THE PRIMARY purpose of a power transformer is to transform energy from one circuit at one potential level to another circuit at another potential level. In some cases, more than two circuits are tied in by the transformer. Depending upon the application of the unit, a few or many specific requirements must be met by the design. Impedances may be specified, efficiencies may be specified, a certain regulation may be required, floor space and total weight may be a limiting factor, shipping dimensions and weight are limitations, temperature limits must be observed, and core and copper losses must meet specified values. These and many more similar characteristics determine the degree of flexibility available to the designer. Because of these varied and interrelated functional characteristics, the designer must consider the design as a whole. One particular requirement cannot be designed for without considering its effect on other requirements. Increasing importance of transformer noise imposes another constraint on the transformer design.

Simultaneous with the imposing of more requirements on the design, the manufacturer has been developing new materials, new manufacturing processes, and improving design practices to enable him to build better, more efficient, and more reliable transformers. While making these changes, the manufacturer has constantly kept in mind the requirements of, and his responsibility to, the customer. Where new materials have been introduced, their ranges of operating temperature, stress, voltage, and flux density have been determined so that the new material would be properly applied in designs.

COST OF NOISE REDUCTION

AT THE present state of the practice, reduction of power-transformer noise levels below present standard values requires either a reduction in operating flux densities

Table I. Representative Frequencies Present in Noise Emitted From 60-Cycle Transformers Rated From 750 Kva to 37,500 Kva

Frequency Component	Decibel Level of Components								
	Transformer								
	A	B	C	D	E	F	G	H	I
120	39.5	44.5	45.5	82.5	59.5	67.0	49.5	73.0	60.5
240	55.0	44.0	56.5	74.0	65.0	62.5	60.5	55.0	51.5
360	35.0	55.5	47.0	76.5	57.0	53.5	54.0	59.5	54.0
480	52.5	55.0	44.5	75.0	57.0	49.0	47.5		53.5
600	36.0	47.0	36.5	69.0	52.5	49.5	42.0	63.5	50.0
720	45.5	48.0	39.5	66.5	54.0	47.0	45.5		47.0
840	43.0			66.0		57.0	47.5		
960	46.0		41.5	61.0	42.0	52.0	50.0	59.5	48.0
1080	48.5			60.5	40.0	63.5	46.5	60.0	44.0
1200	53.5	66.0	54.0	64.5	40.0		55.5	52.5	39.5
1320	44.0			60.5	40.0				
1440	45.0				51.5				
1560	36.5								
1680	40.5				43.0				
1800	36.5				43.5			52.5	

or introduction of acoustic impedances in one or more of the transmission paths. Such impedances may be internal or external to the transformer tank. Either of these reduction methods is expensive and places handicaps on the designer. Lowering noise levels of cooling equipment requires either slow-speed standard fans or redesigned low-noise-level fans which are not as efficient for cooling as present standard fans. Either of these methods is expensive. Therefore, noise-level reductions of the transformer itself are expensive and may necessitate cost increases of power transformers.

The other alternative for obtaining low-noise-level transformer installations is to build walls, barriers, or enclosures around the transformer. This method sometimes requires cooling equipment for the installation, makes it difficult to accommodate incoming and outgoing voltage lines, and, to a certain extent, imposes fire protection and repair handicaps. In metropolitan or residential areas, such measures may have to be used, but at stations remote from such areas or in noisy areas, present standard transformer noise levels would be satisfactory. It appears that installations requiring very low noise levels should be considered as special installations.

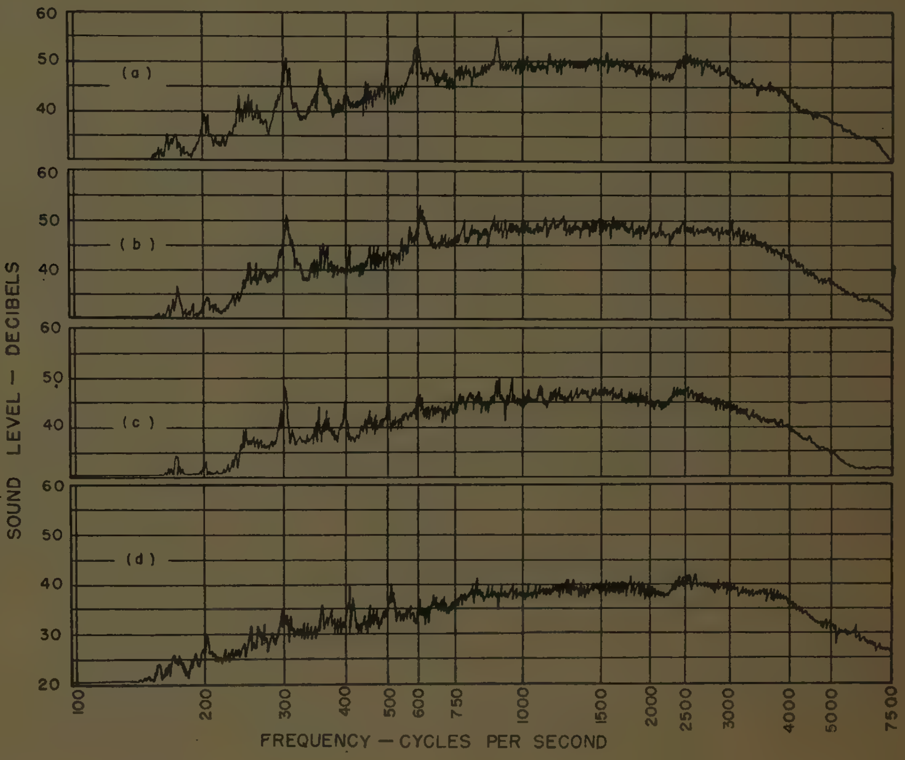


Figure 8. Recordings of representative frequency spectra for transformer cooling fan

Curve	*Degrees From Fan Axis*	*Total Measured Noise Level, Decibels*
A	*0*	*65.2*
B	*30*	*64.8*
C	*45*	*63.0*
D	*90*	*55.5*

Whether extra expense required to obtain a low-noise-level transformer installation be put into the transformers themselves or in walls, barriers, and structures is a matter of which method is less costly. Operators and manufacturers will have to work together to obtain the most desirable solution which will vary with the installation.

CONCLUSIONS

Characteristics of power transformer audio noise vary from one design to another; but the more important characteristics, such as variations with excitation voltage, load, frequencies present, and size of transformer, are fairly well established. Increased importance of transformer noise requires the manufacturer to be very much aware of these characteristics because of the interrelation between audio noise and other characteristics of the transformer.

For special installations, low-noise-level transformers may be designed and built, but they are costly. The other alternative of building enclosures around transformers is also expensive and disadvantageous in other respects. For such installations, the best compromise can best be worked out by the operator balancing costs, advantages, and disadvantages of the two possible methods. Either method will increase cost over that of a standard transformer, but such cost may have to be borne for particular locations.

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Microwave Gas Discharges

M. A. BIONDI

The microwave gas discharge has presented a new field for physical exploration. The results of some of these experiments are given here; processes active in a microwave gas discharge are discussed, and a formula is developed for the complex conductivity of the discharge from the known properties of electrons and ions.

THE microwave gas discharge first became widely known during the development of wartime microwave equipment. It served as the basic mechanism of the transmit-receive switch, a device which protected radar receiver components from damage during the high power transmitter pulse. In addition to offering some difficult engineering problems in the design of transmit-receive switches, the microwave discharge presented a new branch of physics for exploration. In the intervening years the principles and laws governing the microwave discharge have been investigated in a number of experiments. As a result, it is believed that today there is a reasonably complete understanding of these phenomena.

The properties of the discharge which are probably most familiar to the electrical engineer are its conductivity and dielectric coefficient or, in terms of circuit elements, its inductance, capacitance, and resistance. Since a discharge contains charged particles in the form of electrons and ions moving throughout the gas, let us examine the complex conductivity which this medium presents to an applied microwave electric field. The electrons and ions will oscillate in the applied field and, neglecting collisions with gas atoms, their motion is given by

$$\mathbf{F}=e\mathbf{E}=m\frac{d\mathbf{v}}{dt}$$

where **E** is the instantaneous electric field, **v** is the velocity, and e and m are the electron's or ion's charge and mass, respectively. For an alternating field of angular frequency ω the velocity may be written, $v=v_0\epsilon^{j\omega t}$, and hence

$$e\mathbf{E}=j\omega m\mathbf{v}$$

or

$$\mathbf{v}=-j\frac{e\mathbf{E}}{\omega m} \qquad (1)$$

It will be noted that the velocity lags the impressed electric field by 90 degrees. The current density **J** produced by the oscillating charges is given by

$$\mathbf{J}=ne\mathbf{v}=\sigma_c\mathbf{E}=(\sigma_r+j\sigma_i)\mathbf{E}$$

where n is the electron or ion density, and σ_c is the complex conductivity of the medium, σ_r being the real and σ_i the imaginary part of the conductivity.

Thus,

$$\sigma_c=\sigma_r+j\sigma_i=-j\frac{ne^2}{m\omega} \qquad (2)$$

It will be noted that in this case of no gas collisions the conductivity is purely imaginary and depends on the density of charged particles. In an actual discharge, the electron and ion densities are comparable, and since the mass of an ion is thousands of times greater than the mass of the electron, the conductivity due to the ions compared to that of the electrons may be neglected.

A more familiar concept is the dielectric coefficient of a medium, which is related to the conductivity by

$$\sigma_i=(K-1)\epsilon_0\omega \qquad (3)$$

where σ_i is the imaginary part of the complex conductivity, K is the dielectric coefficient of the medium, and ϵ_0 is the permittivity of free space. Substituting equation 3 into 2 we have

$$K=1-\frac{ne^2}{m\omega^2\epsilon_0} \qquad (4)$$

An interesting feature of this formula is that the dielectric coefficient of an electron cloud is always less than one, unlike that of ordinary materials, and in fact may become negative. If such a medium were placed between capacitor plates, the capacity would decrease and could become zero for sufficient electron density. If the density were increased further the capacitor would take a lagging current, that is, become inductive.

If the effect of collisions of electrons with gas molecules is considered, it is found that equation 1, which states that the velocity is 90 degrees out of phase with the impressed field, is no longer valid. Collisions destroy the phase relationship, and hence, there is a component of the electron's velocity which is in phase with the electric field. This in-phase charge motion corresponds to a real conductivity and appears as the resistance of the discharge. The formula for the complex conductivity, considering the effect of collisions between electrons and gas molecules, is

$$\sigma_c=\frac{ne^2}{m}\left[\frac{\nu_c-j\omega}{\nu_c^2+\omega^2}\right]$$

where ν_c is the average collision rate between the electrons and the gas molecules. If the collision rate is made zero,

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Full text of a conference paper presented at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950.

This is the last in a series of four articles on gaseous conduction phenomena. See "Gaseous Conduction Phenomena and Their Application in Electrical Engineering" by J. J. Cobine (*EE, June '50, pp 499–504*), "Mechanism of Spark Breakdown" by L. H. Fisher (*EE, Jul '50, pp 613–19*), and "Fundamental Processes in Gaseous Tube Rectifiers" by A. W. Hull (*EE, Aug '50, pp 705–10*).

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this formula reduces to equation 2. Thus, the unimpeded motion of the electrons gives rise to a negative capacitive or an inductive effect, while collisions with gas atoms result in a resistive effect.

Up to this point we have assumed the existence of electrons and ions in the microwave gas discharge without inquiring as to how the ionization of the gas was accomplished. In the usual d-c or low-frequency a-c glow discharge the potential difference across the tube exceeds the ionization potential of the gas by a large amount. It is reasonable to expect, therefore, that ionization of the gas will take place. As shall be seen shortly, the mechanism of ionization of a gas by a microwave-frequency field involves more subtle considerations.

In the breakdown of a d-c discharge, an initial electron (produced perhaps by the passage of a cosmic ray through the tube) is accelerated toward the anode of the tube and gains energy as it falls through the applied potential. Collisions with gas atoms cause it to lose some energy by elastic recoil, but the electron continues to gain a net energy from the field until it has sufficient energy to excite or ionize a gas atom on collision. The ionizing collision produces a new electron and a positive ion, and the two electrons move on toward the anode, each eventually gaining enough energy to ionize again. This process results in a cumulative ionization known as an avalanche, and the gas breaks down, that is, becomes densely ionized. The foregoing remarks give a highly simplified description of d-c breakdown; however, they do illustrate two important points: (1) the electron gains energy by falling through a portion of the potential difference established between cathode and anode of the discharge tube; (2) the electron loses energy in elastic collisions with gas atoms and would gain energy more rapidly if the gas were not present.

Now the breakdown of a gas under the action of a microwave frequency field will be examined. If collisions with the gas atoms are neglected for the moment, it is found from simple mechanics that the rms velocity of oscillation of the electron, derived from equation 1, is

$$v=\frac{eE}{m\omega}$$

Thus, the mean square energy which the oscillating electron has is

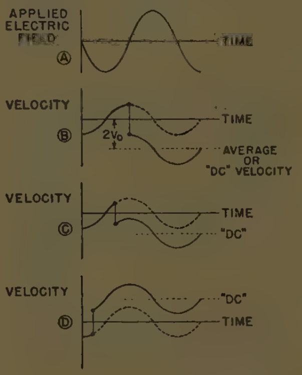
$$T=\frac{1}{2}\,mv^2=\frac{1}{2}\,\frac{e^2E^2}{m\omega^2} \qquad (5)$$

Expressed in electron volts, this energy is

$$\text{Energy (electron volts)}=\frac{1}{2}\,\frac{eE^2}{m\omega^2} \qquad (6)$$

From experimental measurements one finds that in a gas such as helium a field of the order of 200 volts per centimeter is sufficient for breakdown. The frequency of the field in this case was 3,000 megacycles per second. From equation 6 one calculates the energy of the oscillating electron to be about 4 × 10^{-3} electron volt. Since ionization potentials of noble gases are the order of ten volts, we are faced with the apparent paradox that the conditions which are most favorable for an electron to gain energy in a d-c discharge yield electron energies which are far too small to cause breakdown in a microwave field.

The explanation of the mechanism of microwave breakdown lies in the effect of collisions which the electrons make with gas atoms. In d-c breakdown these collisions resulted in an energy loss. In the microwave case the collisions result in similar energy loss, of the order of m/M of the electron's energy (m is the electron mass, and M is the mass of the gas atom); however, they also tend to destroy the time-phase relationship between the electron's motion and the applied electric field. It is this change in phase at collisions which permits the average electron to gain energy in excess of its purely oscillatory energy. This may be illustrated by a simple example. Consider an electron which makes a head-on collision with a gas atom and hence recoils at 180 degrees from its incident direction. Figure 1 illustrates the behavior of this electron for collisions occurring at different times in the a-c cycle. It is assumed that the collision occurs instantaneously on this time scale and results in a reversal of the electron's total velocity vector. In Figure 1*B* the electron collides as the field goes through zero. There results an average or "d-c" component on the oscillatory velocity which is equal to twice the oscillatory velocity amplitude. In Figures 1*C* and 1*D*, collisions occurring at other times in the cycle are illustrated. These collisions result in a smaller "d-c" component than in 1*B*; however, in all cases there is an addition to the purely oscillatory velocity. As a result, the kinetic energy, equal to 1/2 mv^2, is greater, after collision, than the oscillatory energy alone.



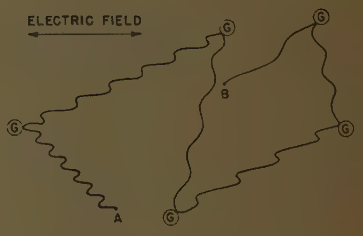


Figure 1 (left). Effect of head-on collisions on electron's velocity

Figure 2 (right). Random-walk motion of an electron colliding with gas atoms

After the electron has gained a d-c component of velocity it may either gain or lose an additional d-c velocity during a second collision; however, it shall be shown that the energy increases on the average after every collision. Suppose two electrons had gained d-c velocity components v_1 by scattering at collisions. At their next collision let the first electron gain a d-c component v_0 and the second electron lose a d-c component v_0. We may write for their d-c velocities after collision

$$v_2=v_1+v_0$$
$$v_2'=v_1-v_0$$

which average to v_1. However, the kinetic energies after collision are

$$T_2=\frac{1}{2}\ m(v_1+v_0)^2=\frac{1}{2}\ m(v_1^2+2v_1v_0+v_0^2)$$

$$T_2'=\frac{1}{2}\ m(v_1-v_0)^2=\frac{1}{2}\ m(v_1^2-2v_1v_0+v_0^2)$$

These two energies average to

$$(T_2)_{av}=\frac{T_2+T_2'}{2}=\frac{1}{2}mv_1^2+\frac{1}{2}mv_0^2$$

The first term, $1/2\ m\ v_1^2$, is just T_1, the energy each electron had before collision. Thus, the average energy change at this collision was $(T_2)_{\text{av}}-(T_1)_{\text{av}}=1/2\ mv_0^2$, which is positive. Thus, scattering collisions result in an increase in the electron's energy.

The foregoing simple example illustrates the case of head-on collisions only and has neglected the random motion of the electrons and the gas molecules. An exact analysis, in which collisions at all angles and the random motion of the electrons are taken into account, gives the result that at a collision the average electron increases its energy by twice the oscillatory energy:

$$\text{Energy gain per collision}=\frac{e^2E^2}{m\omega^2}$$

The number of collisions which electrons must make with gas atoms in order to ionize and hence cause breakdown may now be estimated. It has been seen that, for breakdown of helium in a typical case, the oscillatory energy is about 4×10^{-3} electron volt. Therefore, at each collision between an electron and a helium atom the electron gains an average of 8×10^{-3} electron volt from the field while losing $2m/M$ of its energy to the gas atom by recoil. For helium, $2m/M$ is about 1/3,700; therefore, at low energies the electron gains much more energy from the field than it loses in recoiling from the atom. However, the electron must have about 25 electron volts to ionize helium directly. At this energy, the electron loses

$$\text{Energy loss per collision}=\frac{25}{3{,}700}=6.8\times 10^{-3}\text{ electron volt}$$

while still gaining a constant 8×10^{-3} electron volt. Thus it is seen that at the end of this rather tortuous climb towards ionizing energy the electron is barely gaining energy. To reach ionizing energy the average electron has to make more than 10,000 elastic collisions with helium atoms.

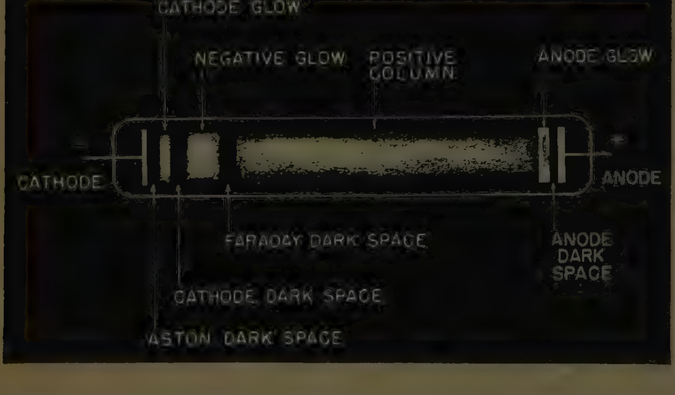


Figure 3. The d-c glow discharge showing eight distinct areas, each of which is the result of a distinct process

Having discussed the means by which ionization of the gas is accomplished in the microwave case, we may now consider the fundamental differences between d-c (or low-frequency a-c) discharges and microwave discharges. In a d-c tube the field applied between the cathode and anode has a constant direction, so that electrons will be accelerated in the same direction, cathode to anode. An electron produced near the cathode by a cosmic ray moves toward the anode, ionizes, and eventually a whole avalanche of electrons to the anode results. In a glow discharge, the ions do not have enough energy to ionize the gas atoms. On the other hand, a given electron must move toward the anode to gain ionization energy. Thus, it is impossible for this electron or any of its progeny produced in the avalanche to produce ionization at a point closer to the cathode than the point at which the original electron was produced because the electrons can not gain energy while moving against the field. Unless we have a constant resupply of electrons near or at the cathode by other means the discharge will go out. A common source of new electrons is found in the bombardment of the cathode by positive ions. A d-c discharge, therefore, is characterized by primary ionization of the gas by electrons moving toward the anode with secondary processes required to replenish the supply of electrons in order to keep the discharge operating.

A low-frequency a-c discharge is quite similar to the d-c discharge. The electric field alternates so that at one instant electrode A is the cathode and electrode B is the anode while a half-cycle later A is the anode and B the cathode. In a fluorescent lamp operating at 60 cycles per second, electrode A remains the cathode for approximately ten milliseconds, which is long compared to the time it takes an electron to move from cathode to anode and be collected. The behavior is therefore d-c-like in that a secondary source of electrons is necessary in order to keep the discharge functioning.

A microwave discharge is characterized by the fact that the electron can move only a very small fraction of the distance across the tube during a half-cycle of the electric field. Using the previous values of 200 volts per centimeter as the breakdown field in helium at 3,000 megacycles per second one finds that the amplitude of oscillation of the electron is of the order of 10^{-3} centimeter. At gas pressures in the millimeters of mercury range the mean free path, that is, the average distance the electron travels before making a collision with a gas atom, is greater than 10^{-2} centimeter. Therefore, the electron makes many oscillations between successive collisions with gas atoms. The motion of the electron is shown schematically in Figure 2.

The motion is made up of two components; the random velocity of the electron (due to scattering at collisions) upon which is superposed a small oscillatory velocity. If the wavy pattern is neglected, it is found that the electron is executing a random type of motion. That is, at each colli-

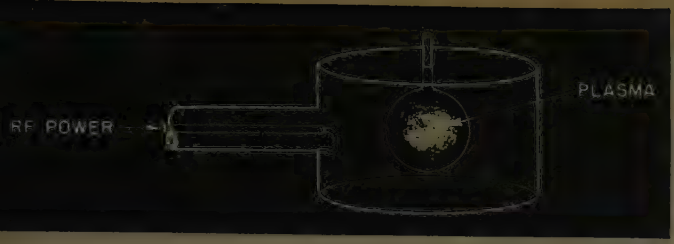


Figure 4. In the microwave discharge there is only a plasma with which to be concerned instead of the eight regions that appear in the d-c glow discharge

ion, the electron is staggered and wanders aimlessly in any given direction until the next collision. This motion is characteristic of a diffusion process in which there is no preferred direction to an electron's motion, and the ultimate distance covered, in this case the length *AB*, is a statistical quantity.

In the d-c case the electron could gain energy only by moving toward the anode. In the microwave case the electron is moving in a diffusion type of motion and, on the average, gains energy after every collision, independent of the direction in which it moves after the collision. Therefore, an initial electron can produce ionization anywhere in the tube, and there is no need for a secondary process to supply electrons. The elimination of secondary processes is a simplification which permits experiments to measure the primary gas ionization directly.

The microwave discharge has a simpler appearance than the d-c discharge. In a d-c glow tube there are the following distinct areas (see Figure 3, not to scale): Near the cathode are the Aston dark space, cathode glow, cathode dark space, negative glow, and Faraday dark space. The majority of the tube is filled with a glowing area called the positive column. Near the anode are the anode glow and anode dark space. Each of these regions is the result of distinct processes and is a subject for study in itself. For example, the cathode glow is the region in which electrons liberated at the cathode have gained enough energy from the field to excite the gas atoms; this results in the luminosity of the cathode glow.

In the microwave discharge (see Figure 4), instead of having eight distinct areas to contend with, there is only a bright region known as a plasma (resembling strongly the positive column of the d-c discharge). In the plasma are found nearly equal concentrations of ions and electrons. Since there is only a single region in which ionization, excitation, diffusion, and other processes are taking place, it is possible to study them and their relationship to the structure of the plasma without the disturbing influence of other regions and other processes. This simplicity of the microwave discharge compared to the d-c discharge has permitted for the first time a completely theoretical calculation of the breakdown voltage, a calculation which was found to agree with experimental measurements within five per cent over several decades of the experimental variables. The simplicity of the microwave discharge has also permitted the first direct measurements of the simultaneous diffusion of ions and electrons. At present there are experiments in progress which study the effects of steady magnetic and steady electric fields on a microwave frequency discharge. These current experiments have a good chance for success because of their fundamental simplicity.

Summarizing the present state of knowledge of microwave discharges, the electrical properties of the discharge, that is, its measured conductivity and dielectric coefficient, are found to agree with theoretical formulas derived from the known properties of electrons and ions moving in a gas. The mechanism by which ionization of the gas takes place is understood and has been tested experimentally. Finally, the relative simplicity of the microwave discharge has permitted simple, direct measurements of the fundamental processes active in the discharge. Much of this new knowledge may be applied to problems in d-c discharge studies with the result that the older field also benefits. This knowledge is also available to permit a more adequate engineering of devices employing microwave discharges.

Future application and improvements may include a better transmit-receive switch to permit shorter resolving times in radar sets, or a microwave modulator with which voice and other information may be transmitted on centimeter-wave-length carriers. Another possibility, proposed by Dr. J. J. Cobine, is a flameless microwave electronic torch, capable of developing very high temperatures. The physics of the microwave discharge is understood; there now remains the problem of exploiting this knowledge in the form of new devices—a problem which belongs to the electrical engineer.

New Electronic Pressure Gauge

Man's nearest approach to a perfect vacuum now can be accurately measured by an electronic pressure gauge 200 times more sensitive than any produced before. The new gauge, manufactured by Westinghouse Electric Corporation, Pittsburgh, Pa., looks like a large radio tube and behaves in a similar manner. Called an "ion gauge," the instrument can detect the presence of air in a vacuum where only one air molecule remains out of every 10,000 billion originally present. So rare are air molecules at this pressure that each one must travel some 500 miles before striking another. In order to measure the pressure in a vacuum, the gauge is sealed tight to the system. When power is turned on, electrons from an electron gun inside the gauge are released. These electrons collide with air molecules in their path, knocking off part of the molecule to create a positively charged particle called an ion. An accurate measure of the pressure inside the vacuum system is the number of ions formed in this way each second, which can be read directly from a meter attached to the system. The new gauge was developed specifically to aid Westinghouse research scientists in studying the behavior of atoms, electrons, and radiation in gas-filled tubes such as fluorescent lamps, electronic tubes, and similar devices. However, the gauge should find widespread use in other fields as well.

Construction of Cold-Cathode Counting or Stepping Tubes

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Electronic digital counters are capable of performing at high speeds many of the functions which are performed at low speeds by chains of relays and mechanical stepping switches. Here is described a new principle of tube construction by means of which the position of a glow discharge can be made to step along a row of cold cathodes under the control of input pulses.

ELECTRONIC digital counters have satisfactorily solved the problem of counting at speeds which are too great for mechanical or electromagnetic counters. These high-speed counters usually employ chains of trigger devices such as hot-cathode multivibrators[1] or cold-cathode glow discharge tubes.[2] Coupling between elements in the chain is arranged so that the triggering of one element prepares or primes the next succeeding element. This article describes a new principle of construction which permits coupling from one cold cathode to the next within a single common tube envelope, thereby considerably simplifying the counting tube and circuit. Only one load resistor and three tube-connection terminals are required, regardless of the number of counting stages, although additional elements are usually required in order to obtain information by other than visual means.[3]

The tubes described here have not been developed for any specific application but have been designed to illustrate the principles of construction and operation. Significant operating parameters and limitations are given, however, and possible methods of utilizing this type of tube are suggested.

Before describing the new tube it seems desirable to review briefly some of the circuit properties of cold-cathode tubes.[2] In such tubes the electrons needed for current flow are obtained from an unheated cathode as a result of ionization and excitation of the gas in the cathode-anode space. The well-known trigger action results from the fact that for a range of values of applied voltage it is possible to obtain either a low or high current, the choice being controlled by ionization conditions within the tube. The low current, of the order of 0.1 microampere or smaller, results from gas amplification of small externally produced current (such as photoelectric emission from the cathode or of ionization produced by cosmic radiation or by radium introduced into the bulb). As a result of the gas amplification process the cathode is bombarded with positive ions, excited gas atoms, and light from the discharge, all of which produce additional electron emission. However, the emission produced in this manner is insufficient to replace the original electrons, and removal of the external source of ionization causes the current to disappear. The discharge is therefore called non-self-sustaining.

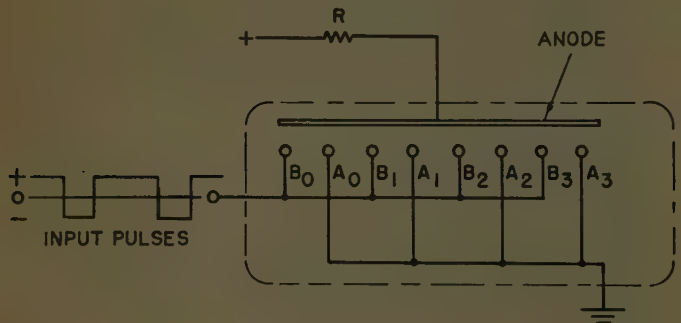

Figure 1. Simple stepping-tube circuit. The cathodes are alternately connected to ground (*A* cathodes) or to the common pulse lead (*B* cathode)

The high-current condition, representing an increase by a factor of 10^5 or greater, is the well-known glow discharge. This is characterized by a steep voltage gradient near the cathode, resulting from space-charge distortion of the field. Each electron leaving the cathode produces enough ionization and excitation in the gas both to maintain the space charge and to extract another electron from the cathode. Since the ionization and excitation required by the high current are also produced by the high current, the glow discharge is self-sustaining once it has been initiated. The voltage across the tube changes only slightly for wide changes in current and has a value, called the sustaining voltage, characteristic of the gas and cathode material.

The transition from low current to high current in a tube of this type is called breakdown. The basic requirement for breakdown is that ions and electrons be introduced into the space between cathode and anode in sufficient numbers to establish a self-sustaining discharge. This is accomplished in a diode by momentarily raising the voltage across the tube to a critical value called the breakdown voltage.[4] If the tube has more than one possible discharge path, breakdown of one path can be aided by ions and electrons from an adjacent path. This process is illustrated by the cold-cathode triode. A main anode voltage which alone is too low to cause breakdown of the tube is enabled to do so when aided by ionization produced in the control gap. A similar

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process is used in the new tube to obtain a particular breakdown sequence required by the stepping function as will now be described.

THE BASIC STEPPING MECHANISM

THE NEW counting or stepping tube has a row of cold cathodes and one common anode. Only one cathode-anode gap is broken down at a time, the discharge progressing from one cathode to the next under the control of a single pulse-input lead. Figure 1 shows the circuit connections of a simple 4-stage tube. The cathodes are alternately connected to ground (A cathodes*) or to the common pulse lead (B cathodes). The common anode is connected to the positive power supply through a resistor R.

Assume that a discharge has been established to cathode A_0. The anode-to-ground voltage will then be equal to the sustaining voltage of the glow discharge. A negative voltage applied to the pulse input lead will cause all of the B cathodes to become negative with respect to the A cathodes. This means that the voltage from anode to the B cathodes is greater than that required to sustain a glow discharge. This voltage, aided by the ionization in the region near A_0, is able to cause breakdown from the anode to either B_0 or B_1. The current to the B cathode causes an increased voltage drop in the anode resistance which lowers the voltage between the anode and A_0 below the sustaining value and extinguishes the glow at A_0. At the end of the driving pulse the voltage on the B cathode becomes positive with respect to that of the A cathodes, and therefore, the voltage from anode to the A cathode exceeds the sustaining voltage. This applied voltage, when aided by the ionization near the B cathode, causes breakdown to one of the A cathodes again. The current to the A cathode lowers the anode voltage and extinguishes the glow at the B cathode.

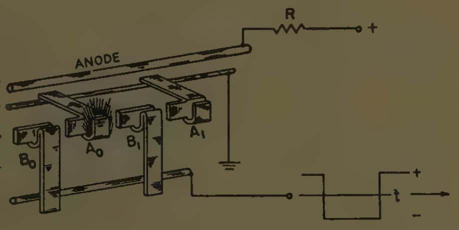

Figure 2. Cathode construction showing hollow cathode preference mechanism

In order to cause the discharge to step along the row it is necessary to provide a preference mechanism which makes the discharge always transfer in the forward direction at the beginning and at the end of each pulse. Thus, in Figure 1, B_1 should be preferred to B_0 at the beginning of the first pulse, and A_1 should be preferred to A_0 at the end of the first pulse. The next pulse should cause the discharge to be picked up on B_2 and then released to A_2 and so on.

One simple means of introducing the preference mechanism is to use specially shaped cathodes shown in Figure 2. These are constructed with a hollow U-shaped portion and an extended plane portion. It is known that a properly shaped hollow cathode is a more efficient cathode in a glow discharge than a plane or convex surface.[5] Consequently, the cathodes shown operate with the glow discharge concentrated in the hollow portion. This concentration is indicated by the shaded area at the right-hand end of A_0. It is seen that the plane portion of B_1 projects into the region of high ionization density, whereas B_0 is located in a region of low ionization density. Therefore, when the negative pulse is applied to both B cathodes, B_1 breaks down more readily than B_0, and the discharge moves in the desired forward direction. During the pulse the discharge concentrates at the right-hand end of B_1 so that the same mechanism operates to cause breakdown to A_1 at the end of the pulse.

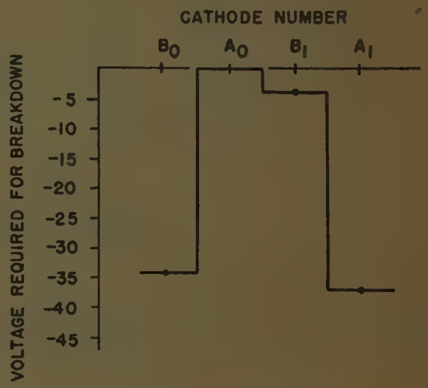

Figure 3. Breakdown voltage for nearby cathodes when discharge is present at cathode A_0

The preference in favor of the forward direction is illustrated by Figure 3 which shows the negative voltage required to cause breakdown to other electrodes in the presence of a discharge to A_0. For example, approximately four volts are required to cause breakdown in the forward direction to B_1 while 34 volts are required to cause breakdown in the reverse direction to B_0.

The wave form of the input pulse is not critical. Sine waves, square waves, and randomly spaced exponential pulses have been used successfully. There is, however, a minimum pulse length and a minimum time between pulses which results from the deionization requirements of the discharge. This can be understood by considering the time during a pulse when the discharge has just been picked up by one of the B cathodes. Successful stepping operation requires that the ionization density near the forward A cathode be greater than that near the backward A cathode at the time the pulse ends. If the pulse is too short, the ionization near the backward A cathode, remaining from the previous discharge, will exceed that near the forward A cathode and faulty operation will occur. The limit for early model tubes has been near 0.5 millisecond minimum pulse length.

METHODS OF UTILIZING STEPPING TUBES

THERE may be some possible applications of the simple stepping tube where visual observation of the position of the spot would yield the necessary information about the number of input pulses. In this case the three external circuit connections and the single load resistor of Figure 1 would be sufficient. The cathodes might be arranged in a circle, the number of input pulses being given by the difference between the initial and the final position of the discharge. A fourth external connection is needed to assure that the counting will always start from the same normal or zero position. A simple method of accomplishing this is to make the connection to cathode A_0 of Figure 1 by means of a separate lead wire brought out through the tube envelope. By applying a large negative pulse to this electrode, the discharge can be brought back to normal or home position in preparation for counting a group of pulses. The number of stages can be increased to any desired value without requiring more than the four external connections. Mechanical and space considerations, however, would place a limit on the number of stages which are permissible in a single envelope.

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* It should be noted that the letter A refers to a particular group of cathodes and is a departure from the conventional use of this letter for anode.

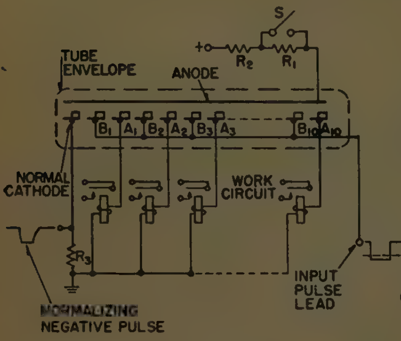

Figure 4 (left). A 10-stage counting tube having output connections for each stage

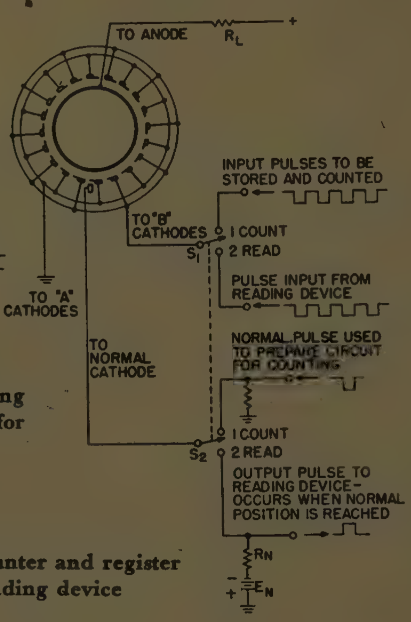
TO ANODE
RL
+
0
TO "A" CATHODES
TO "B" CATHODES
TO NORMAL CATHODE
INPUT PULSES TO BE STORED AND COUNTED
S1
1 COUNT
2 READ
PULSE INPUT FROM READING DEVICE
NORMAL PULSE USED TO PREPARE CIRCUIT FOR COUNTING
S2
1 COUNT
2 READ
OUTPUT PULSE TO READING DEVICE-OCCURS WHEN NORMAL POSITION IS REACHED
RN
EN
-
+

Figure 5 (right). Simple 10-stage counter and register requiring a counting type of reading device

Instead of a simple visual indication, it is usually required that an electrical signal be available to operate a relay or tube in accordance with the number of input pulses. One method of accomplishing this is to connect a load in the cathode lead wire of each of the *A* cathodes. This is illustrated in Figure 4. The tube is made ready for a count by applying a negative pulse to the normal cathode as indicated. This causes the discharge to be established on the normal cathode regardless of where it may have been left by a previous operation. As has already been described, each negative input pulse causes the discharge to move one stage; the final position of the discharge then corresponds to the number of input pulses. In the usual application, resistors R_1 and R_2 would be large enough to limit the current to a value below the operate current of the relays. After the completion of the counting, switch *S* is closed. This increases the tube current and operates the relay corresponding to the number of input pulses. This method requires an external lead wire for each counting stage in addition to leads for the normal electrodes, the pulse input lead, and the anode, making a total of 13 leads for a 10-stage counter.

When it is desirable to have a large number of simple counter tubes combined with a single somewhat more complicated reading device, the arrangement of Figure 5 may be used. Only four external tube connections are required. With the switches in position 1, counting is accomplished in the manner already described for visual reading; a normalizing pulse is used to start the count from the proper point, and the input pulses move the discharge one stage at a time. Reading is accomplished with the switches in position 2. The reading device supplies pulses and counts the number necessary to bring the discharge back to the normal position. A positive pulse is developed at the normal cathode at the time the discharge reaches the normal position. This positive pulse indicates that the sum of the original number of input pulses plus the number supplied by the reading device equals the fixed total number of stages in the tube. If resistor R_n is small and voltage E_n is sufficiently large, the discharge can be held at the normal position even though the reading device continues to send pulses. This leaves the discharge in the proper position for starting the next counting cycle.

In the circuit of Figure 5, the switch S_1 is kept in position 1 and S_2 is kept in position 2, it will be noted that one output pulse is obtained for each ten input pulses. If E_n and R_n are chosen so that the discharge is not held at the normal position, the tube operates as a frequency divider with a division ratio determined by the number of stepping stages.

Figure 6 shows a tube constructed to perform the simple counting function described in connection with Figure 5. The glass envelope is cut away in order to show the electrode structure.

PERFORMANCE CHARACTERISTICS

It is possible to define and measure some of the performance characteristics of cold-cathode stepping tubes in a manner which makes the data useful for several different applications. These definitions, together with some typical data, are given in the following paragraphs.

During the interval when pulses are being supplied to the pulse lead, transfer of the discharge should always occur in the forward direction. This has been discussed in connection with the curves of Figure 3 which show that four volts are required to cause breakdown to the forward cathode while 34 volts are required to cause breakdown to the backward cathode. The difference between the breakdown voltages to the forward and backward cathodes (30 volts in this case) may be called the counting margin. This margin is dependent on the tube geometry and filling gas as well as on the operating anode current. Figure 7 shows counting margins as a function of operating current for two different tubes.* Tube 1 has a geometry similar to that shown in Figure 2 while Tube 2 has larger and more widely separated cathodes.

Some of the operating circuits described have included resistors or relays in series with the *A* cathodes. It can be seen that voltage developed across a cathode load makes that particular *A* cathode positive with respect to all the others. The maximum voltage which can be developed across the cathode load is limited by the tendency to transfer either forward or backward to the next *A* cathode. This limiting load voltage at which transfer takes place to the next *A* cathode may be called the output voltage margin. As with the counting margin, it is a function of tube geometry and gas filling and of the tube operating current. The output voltage margin is also dependent on the voltage to which the *B* cathodes are connected during the interval between counting pulses.

Figure 8 shows output margins as a function of tube current for two different tubes and for two different return voltages for the *B* cathodes.* As indicated on this figure, connecting the *B* cathodes of Tube 2 to +45 volts gives higher output margins than allowing the *B* cathodes to operate at the floating potential.

The life of cold-cathode tubes is limited by the sputtering of cathode material resulting from positive-ion bombardment and by clean up of the filling gas. Both of these effects can be minimized by keeping the current density on the cathode surface at a low value. In many applications the tube may be required to pass current only a small fraction of the time. Because there is no deterioration during standby periods, such intermittent operation may give very long life for a tube. By using pure metal cathodes, such as molybdenum, and keeping the current density low, it is possible to obtain an operating life of several thousand hours. Intermittent operation may easily permit such a tube to be useful for periods of many years.

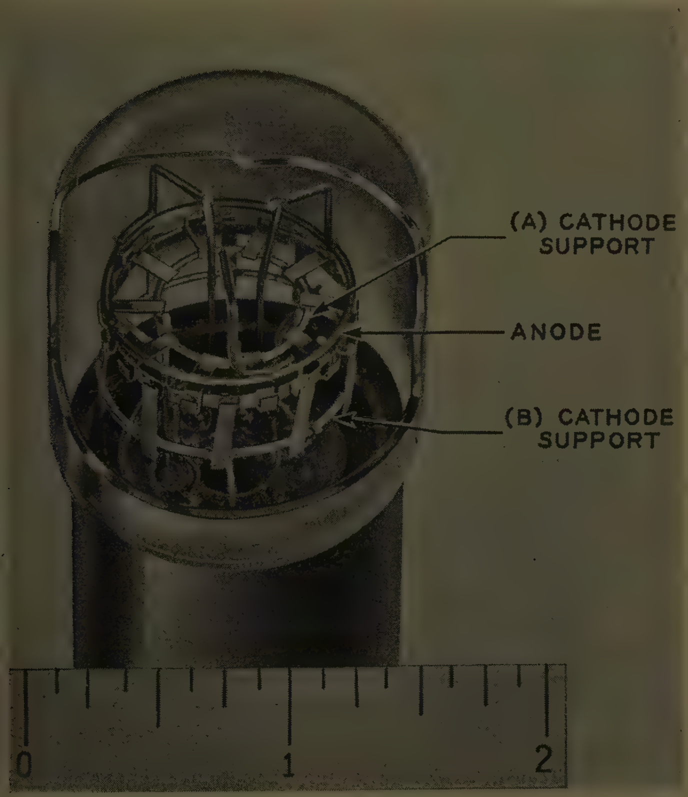

Figure 6. Simple 10-stage tube having the cathodes connected together inside the tube envelope

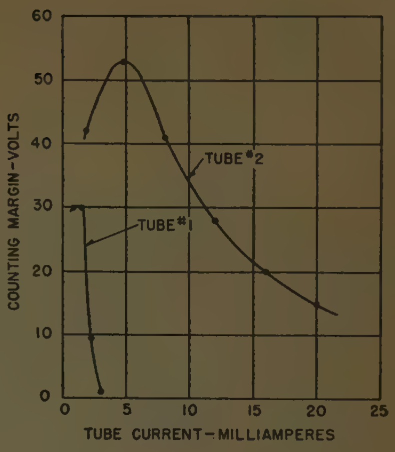

Figure 7. Counting margin as a function of operating current for typical cold-cathode stepping tubes

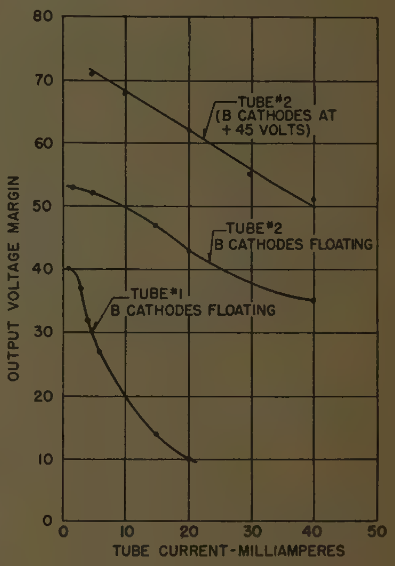

Figure 8. Output margin as a function of operating current for typical stepping tubes

CONCLUSIONS

The principles of tube construction described in this article make possible a new type of cold-cathode tube which has a number of desirable operating characteristics. The input signal need not have a critical amplitude or wave shape, and pulses can be applied at any frequency up to the limit set by deionization time. The driving power required is small enough to be supplied easily by electronic devices, and the output power is large enough to operate electromechanical devices such as relays. The absence of filament standby power makes intermittent operation economical and extends the tube life. These operating characteristics are obtained with a compact physical size and a small number of associated circuit elements. The cold-cathode stepping tube is a new tool which should prove to be useful in a variety of applications where it will replace chains of relays and mechanical switches.

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* These data apply to tubes having pure molybdenum cathodes and neon filling gas.

Modern Servomechanism Testers

G. A. KORN   T. M. KORN

The method now generally used in testing mechanical and electromechanical servomechanisms requires the taking of simultaneous oscillograph recordings of the input and output of the system under test. Several methods which permit direct reading of amplitude and phase for servomechanism testing are presented and discussed in this article.

DURING recent years the so-called steady-state or frequency response method of evaluating the performance of linear servomechanisms has gained increasing favor over transient response methods.[8] The essential reason for this is the relative ease of inferring the frequency response of a complicated system from the frequency responses of its components.

All the frequency response methods of evaluating the performance of servomechanisms involve the comparison of the system output phase and amplitude with those of a sinusoidal input signal. The attenuation and phase shift of the servomechanism are obtained as a function of the frequency of the sinusoidal input signal and can then be plotted on a Nyquist plot or a phase-decibel diagram for an evaluation of the system frequency response.

The present method of determining the frequency response of a control system requires the taking of simultaneous oscillograph recordings of the input and output of the system under test. Amplitudes and phase differences are obtained from these records by direct measurements, a procedure which is expensive as well as laborious. Methods to obtain these data by direct reading have been used for a number of years by several laboratories.* Such direct-reading methods

1. Permit the immediate plotting of system response curves from calibrated indicating dials. The oscillograph method requires time-consuming data transcription before the system response can be plotted.

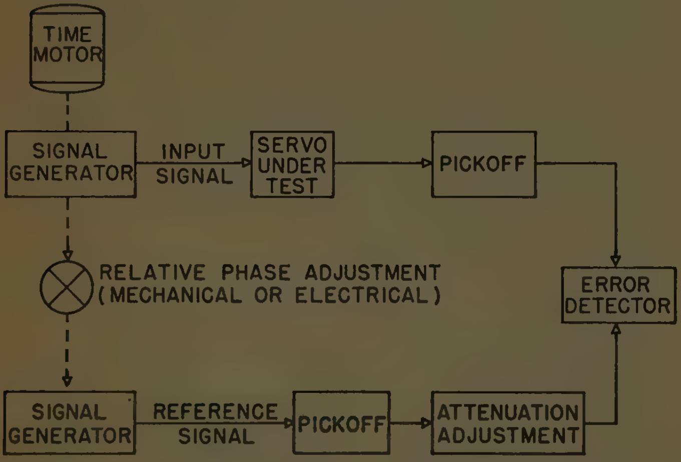

Figure 1. General block diagram of direct-reading servo-mechanism test systems

2. Permit the immediate checking of any doubtful points and the taking of any desired additional points as the shape of the curve becomes apparent. With the present method, many oscillograph records must be filed for reference after the curves have been plotted and the tests completed.

3. Facilitate the simultaneous testing of several control systems with a minimum of equipment. The oscillograph method would be impractical since it requires duplication of expensive equipment and a large number of transcribing personnel.

All of the test systems comprise, in one form or another, the following components:

1. A source of sinusoidal displacements of variable frequency to provide mechanical or electrical inputs to the servomechanism system under test. This is usually a variable-speed "time motor," driving linkages, selsyns, and other signal generating devices. The speed of the "time shaft" is varied to change the frequency of the sinusoidal displacements. The speed may be accurately measured by means of a stroboscopic disk on a high-speed shaft.[1] As an alternative method, a rate servomechanism with calibrated degrees of speed feedback may be used as a variable speed motor.

2. One or more pickoffs to provide electric signals proportional to the mechanical outputs of the servomechanism under test. The electrical quantity varied may be either a direct voltage or the amplitude of a modulated a-c carrier voltage.

3. A source of an electric reference signal whose phase and attenuation may be changed by means of direct-reading dials. The calibration of the dial can be referred to the predetermined input of the servomechanism which is under test.

4. An error detector which indicates existing differences in phase and amplitude between the output and reference signal. The phase and amplitude of the output signal can then be read directly from the dials.

A general block diagram for these systems is shown in Figure 1.

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* One example of these commercial developments in the field is the servomechanism analyzer developed and marketed by Flight Research Engineering Corporation, Richmond, Va.

G. A. Korn is with the Lockheed Aircraft Corporation, Los Angeles, Calif.

T. M. Korn was formerly with the Boeing Airplane Company, Seattle, Wash.

NULL INDICATOR SERVOMECHANISM TESTERS

THE VARIATIONS of this system shown in Figures 2 and 3 represent only a few of the possible combinations of signal and reference sources, pickoffs, and phase adjusting devices. Several types of error detectors will also be described here.

The arrangement of Figure 2 will serve as a first example. It is applicable to servomechanisms requiring a mechanical input signal such as cam-following lathes or milling machines. In this particular arrangement, the reference signal, as well as the mechanical servomechanism input, is obtained from the time shaft through linkages (scotch yokes) which have been coupled mechanically through a differential.

This differential permits an adjustable phase difference to be inserted between the servomechanism input and the reference source. Mechanical differentials are readily available from surplus fire control computers. The electric reference signal is obtained from a simple linear potentiometer positioned by the second scotch yoke. The amplitude of the reference signal is adjusted by the potentiometer *D*. The scale of this potentiometer may become nonlinear due to loading. Since, however, this potentiometer would be calibrated logarithmically, the nonlinearity will not present any problem.

A 60-cycle-per-second a-c signal proportional to (−1) times the output of the servomechanism under test is obtained from a pickoff potentiometer positioned by the servomechanism output. This negative output signal is added to the reference signal by the summing network shown. The oscilloscope vertical amplifier is thus presented with a 60-cycle-per-second a-c signal proportional to the difference between the output signal and the reference signal. The oscilloscope will indicate a null clearly if, and only if, these two signals are equal in both amplitude and phase. It is then possible to read the phase shift and attenuation of the servomechanism directly on the phase and attenuation dials.

The second scotch yoke of Figure 2 could be replaced, if desired, by a motor-driven sinusoidal-function generator-potentiometer of the type used in electronic computers or any other "electromechanical-modulator"[1] capable of producing an electric signal proportional to the sine of the time shaft displacement.

Figures 3 and 4 show testers for servomechanisms requiring electric input signals. In Figure 3, an a-c signal modulated sinusoidally with the frequency of the time shaft is obtained from a selsyn or autosyn transmitter mounted on the time shaft.

A measurable phase difference could be added by means of a differential as in Figure 2, to the displacement of a second selsyn transmitter used to obtain the reference signal. The arrangement shown in Figure 3 is, however, more suitable in that the second selsyn is not required to rotate continuously with the time shaft. The 3-phase stators of the two selsyns are connected together so that identical rotating magnetic fields exist in both of them. The reference output is taken from the fixed rotor of the second selsyn. The reference phase can be changed simply by turning the second rotor by means of a properly calibrated

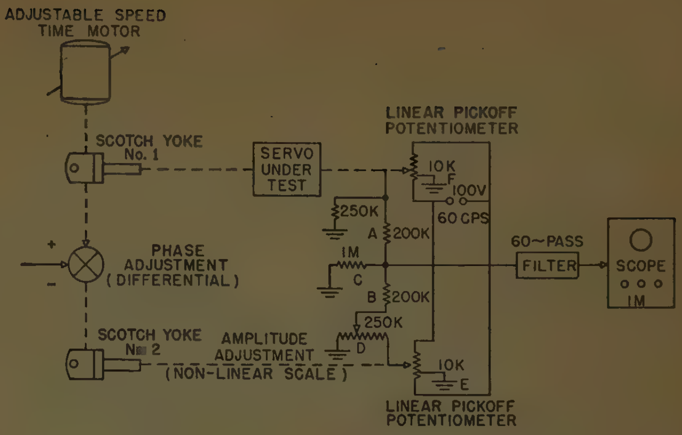
ADJUSTABLE SPEED TIME MOTOR
SCOTCH YOKE No. 1
SERVO UNDER TEST
LINEAR PICKOFF POTENTIOMETER
10K
F
100V
60 CPS
250K
A
200K
IM
C
B
200K
250K
60~PASS
FILTER
SCOPE
IM
+
−
PHASE ADJUSTMENT (DIFFERENTIAL)
SCOTCH YOKE No 2
AMPLITUDE ADJUSTMENT (NON-LINEAR SCALE)
D
10K
E
LINEAR PICKOFF POTENTIOMETER

Figure 2. Null indicator servomechanism tester using two scotch yokes

Filter is high-impedance to ground tuned to pass 60 cycles per second. Obtain wave forms at A and B

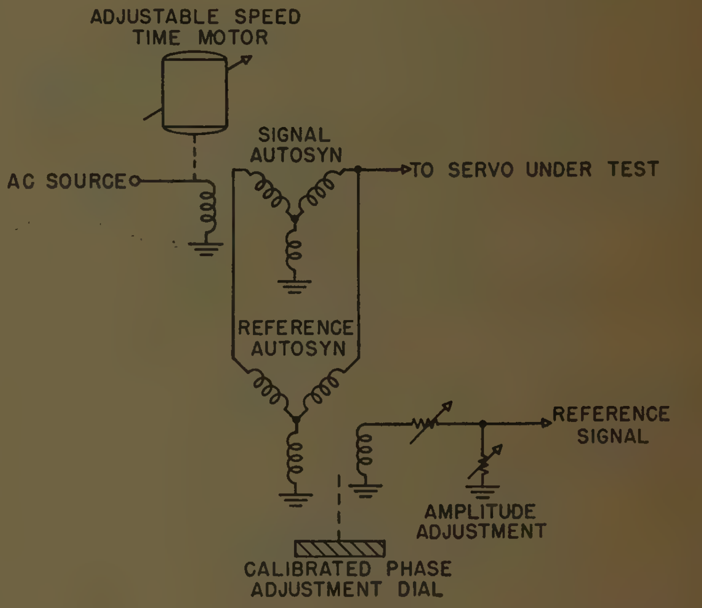

Figure 3. Servomechanism tester using an a-c signal input modulated sinusoidally with the frequency of the time shaft

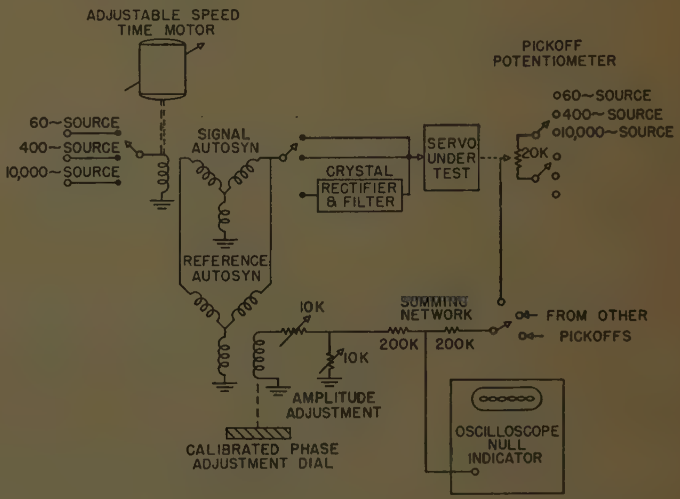

Figure 4. Servomechanism tester using a d-c signal input obtained by exciting one of the autosyns with 10,000-cycle alternating current and rectifying the output with a simple crystal diode

dial. The tester is operated exactly as the tester shown in Figure 2.

One possible arrangement for testing servomechanisms requiring a d-c input signal would be to obtain both the sinusoidally modulated direct voltage for the servomechanism input and a sinusoidally modulated a-c reference signal by means of sine potentiometers on the time shaft. The phase difference would be introduced by means of a differential selsyn.

A better design, shown in Figure 4, has a pair of autosyns as arranged in Figure 3. The d-c input for the servomechanism is obtained by exciting one of the autosyns with 10,000-cycle-per-second alternating current and rectifying the output by means of a simple crystal diode. A selector switch makes 60-cycle-per-second and 400-cycle-per-second a-c signals as well as d-c signals available, so that a very versatile tester results. Whenever 10,000-cycle-per-second carriers are used some care may be necessary to make the relative carrier phases in the two branches of the summing network equal.

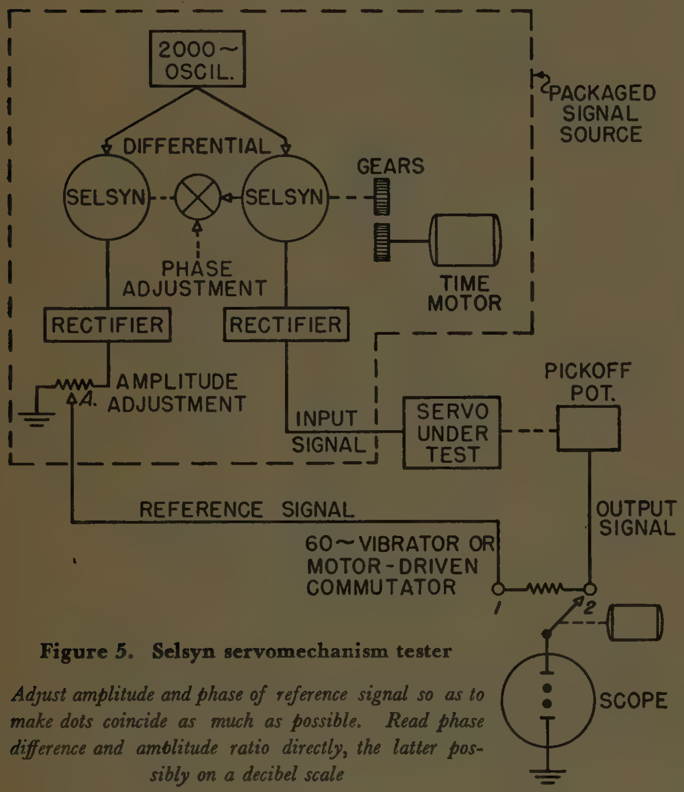

Figure 5. Selsyn servomechanism tester

Adjust amplitude and phase of reference signal so as to make dots coincide as much as possible. Read phase difference and amblitude ratio directly, the latter possibly on a decibel scale

No expensive power supplies are required for any of the servomechanism testers described, as only simple a-c sources are needed. It is also still possible to record the actual servomechanism output wave forms by means of the pickoff potentiometer provided.

Several different outputs from the servomechanism can be tested by inserting as many pickoffs as quantities to be measured. A selector switch can be used to connect the outputs, one at a time, into the test circuit.

Using the 10,000-cycle-per-second carrier scheme, the authors have measured phase angles with a consistent accuracy of better than one degree. A sharp null indication was obtained and operation of the tester was completely satisfactory.

ALTERNATIVE ERROR DETECTORS

In the "trapezoid pattern" method of phase comparison,[3] a direct voltage proportional to the servomechanism output displacement is obtained by means of a linear pickoff potentiometer. This direct voltage is applied to the horizontal plates of an oscilloscope, while the a-c carrier modulated with the reference signal is applied to the vertical plates.

By adjusting the phase dial, the elliptical bases of the Lissajous figure are made to collapse into straight lines and the angle is then read directly as before. The oscilloscope can be calibrated as a voltmeter and the amplitude ratio can then be read directly from the oscilloscope. This method would permit the complete adjustment of phase at one time instead of the successive adjustments of both phase and amplitude required by the null method. However, a long-persistent screen would be required for this trapezoidal method.

In the arrangement of Figure 5 both the servomechanism output signal and the reference signals are modulated onto a direct voltage. A commutator or vibrating relay applies these voltages alternately in rapid succession to the vertical plates of an oscilloscope. Two oscillating dots will be observed on the screen, one corresponding to the reference signal and one to the servomechanism output. These two signals are equal when the two dots coincide. A sweep voltage may or may not be applied to the horizontal plates during this test.[1]

Several arrangements permitting instantaneous direct-reading of the attenuation and phase of a servomechanism under test are possible. It is possible, for instance, to use servomechanisms for adjusting the amplitude and phase of the reference signal automatically so that they are equal to the amplitude and phase of the servomechanism output signal, which can then be read directly on the respective dials. Such servomechanism testers which can be read directly on calibrated dials, are still in the development stage.

CONCLUSION

For the testing of servomechanisms requiring electrical input signals, packaged sources of sinusoidal input and reference signals of variable frequency, such as that shown in Figure 4, are very convenient and form a valuable addition to laboratory test equipment. Given such a signal source an ordinary oscilloscope may be used as an error detector for accurate measurements of servomechanism attenuation and phase shift.

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Ferromagnetic Domains

H. J. WILLIAMS

Ferromagnetism is based on the property of domains. These are tiny regions within a magnetic substance. They have this special characteristic: most of the elementary atomic magnets contained in a particular domain have their spins oriented in the same direction. Domain sizes and shapes are the result of an attempt of the ferromagnetic system to reach a state that minimizes the magnetostatic, magnetostrictive, domain-boundary, and other energies.

A FERROMAGNETIC crystal is composed of small regions or domains which are magnetized to saturation. When the crystal is unmagnetized the domains are arranged so that the net magnetization is zero. The application of a magnetic field changes the domain structure. The domains that are favorably oriented with respect to the applied field grow at the expense of those less favorably oriented, so that the net magnetization is no longer zero.

In 1905 Langevin[1] developed the theory of a perfect paramagnetic substance. He assumed that each atom was endowed with a magnetic moment, and that the atoms were far enough apart so that there was no mutual interaction between their magnetic moments. When a magnetic field is applied the atoms tend to line up with their magnetic moments parallel to the field, but this tendency is opposed by the thermal agitation so that a statistical equilibrium is set up. Application of Maxwell-Boltzmann statistics permits calculation of the net magnetization as dependent on field and temperature.

The curves of Figure 1 show the intensity of magnetization for a paramagnetic material as a function of the applied magnetic field. The lower curve is the hyperbolic cotangent relation derived by Langevin. Here, μ_A is the magnetic moment of an atom, H is the applied magnetic field, k is the Boltzmann constant, T is the absolute temperature, and I_0 is the value of the intensity of magnetization at saturation. Langevin assumed that the magnetic moment could occupy any angular position with respect to the applied field. This assumption is changed by the quantum theory which states that there are only a limited number of possible orientations, that is, that there is space quantization. The upper curve was derived assuming that the atomic moments could be either parallel or antiparallel to the applied field. The important point to notice is, that for an ensemble of atomic magnets like this, when there is no interaction between the elementary magnets, enormous fields are necessary to overcome the thermal agitation and saturate the material. The curves show that with the highest fields thus far attained in the laboratory (about 300,000 oersteds), the magnetization approaches only a small fraction of its final value.

If thermal agitation exerts such a disordering force, how is it that some ferromagnetic materials can be practically saturated in a comparatively weak field? This question was answered by Pierre Weiss[2] in 1907 as will be shown.

He assumed the existence of an internal field, proportional to the intensity of magnetization, that aids the applied field H. That is, H is replaced by $H+NI$. When this is used in the hyperbolic tangent or quantum-mechanical modification of Langevin's expression, one obtains

$$\frac{I}{I_0}=\tanh\frac{\mu(H+NI)}{kT}$$

This equation is one of the most important equations in the theory of ferromagnetism. It indicates that even in zero applied field there is still a magnetization of considerable magnitude, when the temperature is below the Curie temperature.

The nature of the Weiss molecular field was not explained until 1926 when Heisenberg[3] showed that it was due to the quantum-mechanical force of exchange. It was then known that the atomic magnetic moments are due to

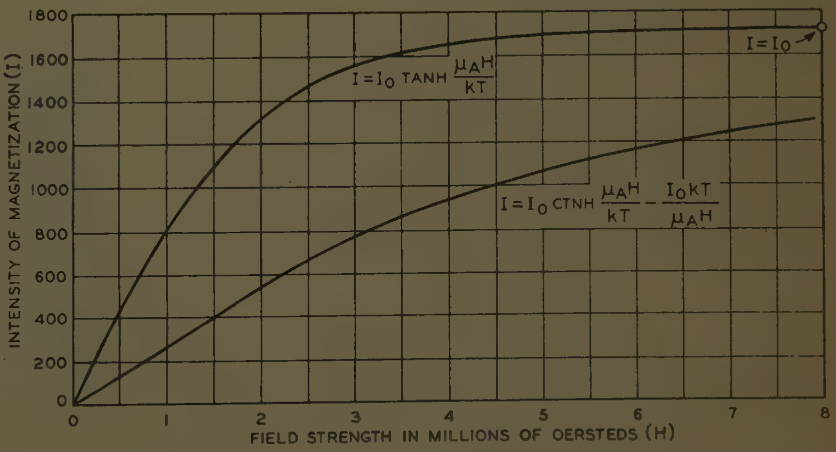

Figure 1. Theoretical curves for the intensity of magnetization versus field strength when there is no mutual interaction between the atoms. The lower curve is the Langevin function; upper curve is quantum-mechanical modification

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This work has been described in more detail in articles by Williams, Bozorth, and Shockley,[12] Williams and Shockley,[13] and Kittel.[14] The author wishes to thank J. G. Walker for very skillful assistance with the preparation of the crystals and the photographic work, P. P. Cioffi and R. J. Morris for making the flux measurements with the Cioffi recording fluxmeter, and Matilda Goertz for very valuable assistance in the preparation of the article. The following illustrations are reprinted from the *Physical Review* by courtesy of the publishers: Figures 4, 6, 7, 9–11.

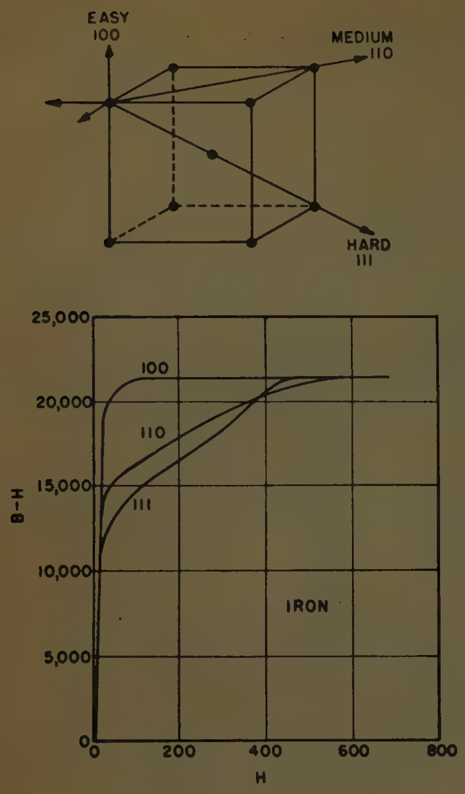

Figure 2. Crystal structure of iron (above) and magnetization curves (below) in principal crystallographic directions. The difference in energy required to magnetize the crystal in the "easy" direction and the "hard" direction is called the anisotropy energy

spinning electrons. Some of the spins cancel others and it is only the uncompensated spins which are responsible for ferromagnetism. It was demonstrated that the exchange forces tend to keep these spinning electrons parallel. Below the Curie temperature the exchange forces overcome the forces of thermal agitation and the material is spontaneously magnetized.

If this is true then how can a magnetic material apparently be unmagnetized at room temperature? Weiss answered this question by postulating that below the Curie temperature the material consists of small regions or domains which are magnetized to saturation but are so oriented that the net magnetic moment is zero. These small regions, each magnetized to saturation, are the Weiss magnetic domains and this is how the concept of magnetic domains originated. Below the Curie temperature, the application of a magnetic field merely lines up the magnetic domains so that the net magnetization increases from zero to saturation for a relatively weak field.

ENERGY OF FERROMAGNETIC CRYSTALS

Anisotropy Energy. The exchange interaction tends to keep the spins parallel. It is equally effective in maintaining parallelism in any direction in the crystal. However, there are crystal forces which tend to make the spins point or lie along certain preferred crystallographic directions.

Figure 2 shows the magnetization curves for iron for various crystallographic directions (Honda, Masumoto, and Kaya, 1928). The unit cell is shown at the top. The upper curve is the magnetization curve for a crystal magnetized parallel to a [100] direction, that is, along a cube edge which is a direction of easy magnetization. The middle curve is the magnetization curve for the [110] direction, parallel to the face diagonal. The lowest curve is that for the [111] direction, the body diagonal, which is the direction of hard magnetization. These curves show that more energy is required to magnetize a crystal, that is, to align the spins, along a [111] direction than along a [100] direction. The excess energy is called the anisotropy energy.

Magnetostatic Energy. If the magnetization of a single crystal (Figure 3*a*) is so arranged that all the magnetization is parallel to one direction of easy magnetization, then a pole is formed at each end (Figure 3*b*). The energy required to form these poles is called magnetostatic energy. If part of the magnetization is reversed, there will be north and south poles at each end (Figure 3*c*). This, however, is not a structure of minimum energy because the flux still must pass through the air going from one domain to another. If, however, as shown in Figure 3*d*, the flux passes through the material, no poles are formed at the ends or at the domain boundary, if the latter makes equal

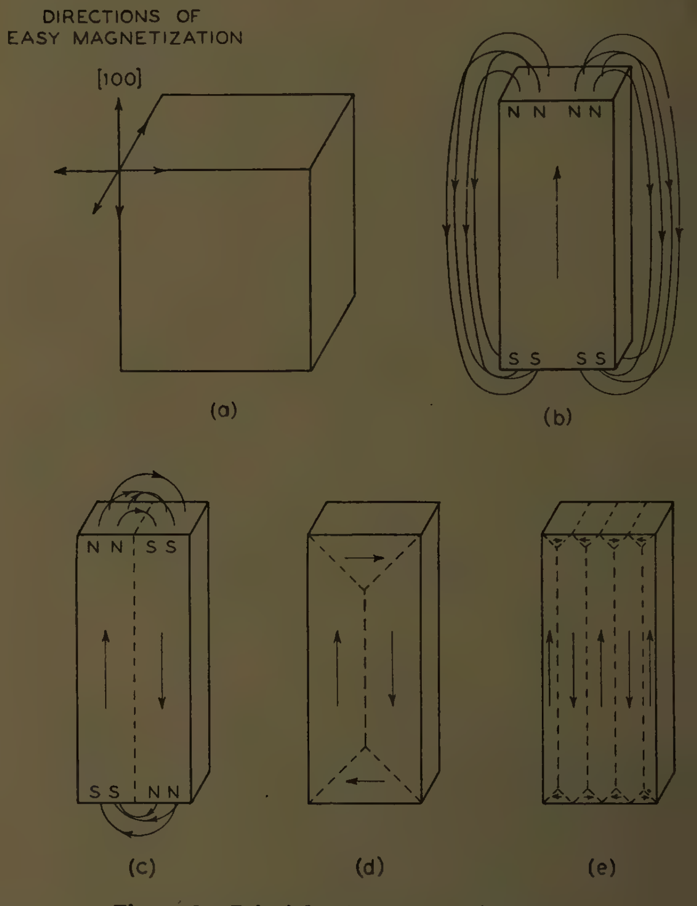

Figure 3. Principle of magnetostatic energy

(*a*). *Directions of easy magnetization in a silicon–iron crystal*

(*b*). *When all the magnetization is in one direction of easy magnetization, a north pole is at one end and a south pole is at the other end. This arrangement has a high magnetostatic energy*

(*c*). *Crystal having two domains. The magnetostatic energy is lower than that of* (*b*)

(*d*). *A domain of closure at each end eliminates the magnetic poles and the magnetostatic energy*

(*e*). *Increasing the number of domains decreases the total volume of the domains of closure* angles with the magnetization on each side. Another way of looking at this is that no poles will be formed at a boundary if the component of magnetization normal to the boundary is constant across the boundary, as has been pointed out by Landau and Lifshitz.[4] The triangular domain which carries the flux from one region to the other is called a domain of closure because it forms a closed flux path in the crystal. In this arrangement there are no poles, so the magnetostatic energy is a minimum. The magnetization in each domain is parallel to a direction of easy magnetization, and, therefore, the anisotropy energy is a minimum. There is another important form of energy which has to be taken into consideration.

Magnetostrictive Energy. If a crystal having a domain structure of this kind is cooled down through the Curie temperature, then as it becomes magnetic the domains tend to elongate in the direction of magnetization and to contract laterally, thus setting up magnetostrictive stresses in the domains of closure. The energy due to these stresses is called the magnetostrictive energy, and can be decreased by forming more domains because the total volume of the domains of closure is then decreased, as can be seen by comparing Figure 3*d* with Figure 3*e*. The volume of the domains of closure has been decreased but in so doing the number of domain boundaries has been increased. These boundaries are called Bloch walls, after Felix Bloch[5] who worked out the theory of the wall in 1932. The formation of a wall requires approximately one erg per square centimeter. Therefore the wall energy has to be taken into consideration. If there are too many domains the wall energy predominates, and if there are too few, the magnetostrictive energy predominates. Thus a maximum and minimum problem presents itself, the stable arrangement being that for minimum total energy. When this is solved it is found that the domain width varies as the square root of the length.

It has been shown that below the Curie temperature the forces of exchange overpower the forces of thermal agitation and tend to keep the spins parallel. The crystal anisotropy forces cause them to lie along certain preferred crystallographic directions; in the case of iron these are the crystal axes. The spins do not all lie along one preferred direction because poles would be formed and a high magnetostatic energy would result; so some domains are formed with their spins parallel to other crystal axes, and arranged so as to eliminate magnetic poles or magnetostatic energy. This energy is eliminated at the expense of an increase in wall and magnetostrictive energy. Then the magnetostrictive and wall energies determine the size of the domains.

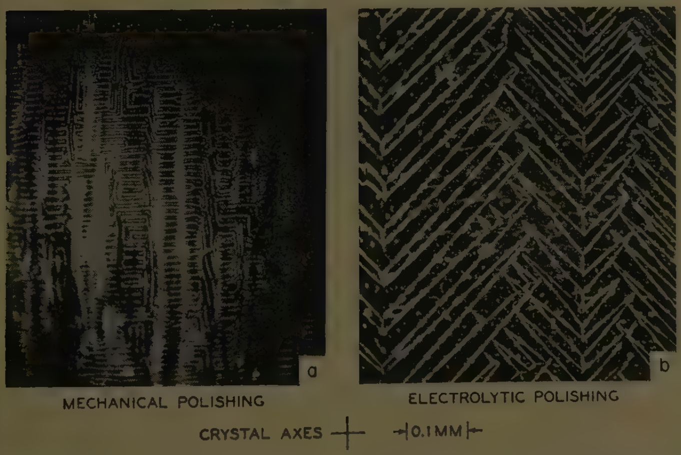

Figure 4. **Comparison of powder patterns (*a*) after mechanical polishing and (*b*) after electrolytic polishing**

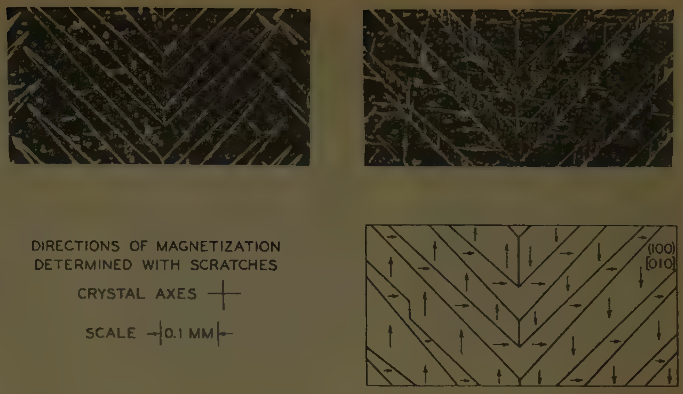

Figure 5. **Patterns obtained on surfaces having very fine scratches. Pattern at left is a typical tree configuration. Pattern at top right was obtained on surface having vertical and horizontal scratches. Drawing shows direction of magnetization in the domains**

These considerations have all been for zero applied field. When a field is applied the energy of the domains in a field has to be taken into consideration.

POWDER PATTERN TECHNIQUE

The magnetic domains can be observed by a technique which is analogous to the well-known procedure of sprinkling iron filings around a magnet to show its field, or sprinkling iron powder on a large piece of magnetized iron to detect flaws or cracks. To observe the domains a surface of a crystal is polished and then a drop of colloidal magnetite is placed on the surface, and a cover glass is placed on the drop so that a thin layer of colloid is left between the cover glass and the surface of the crystal being studied.

The stray fields of the domains extend above the surface of the crystal, attracting the particles of magnetite and causing them to collect along the domain boundaries, thus showing the outline of the domains. This technique was started independently by Bitter[6] in this country and by von Hámos and Thiessen[7] in Germany, and was greatly improved by Elmore and McKeehan.[8–10] Figure 4 shows patterns obtained on a crystal having the surface approximately parallel to a (100) plane which is the cube face. The first pattern, called the maze pattern, was obtained after mechanical polishing using the conventional technique used by metallographers. This type of pattern is thought to be due to the strained material on the surface. The second pattern was obtained on the same surface after electrolytic polishing, as suggested by Elmore. This technique removes the strained material and produces patterns which are representative of the underlying domain structure. The light lines are due to the accumulation of particles of magnetite at the domain boundaries. This is called the tree pattern, because the vertical lines resemble the trunks of trees and the tapered regions the branches. The crystal axes and the scale are shown at the bottom.

TECHNIQUES FOR DETERMINING DIRECTIONS OF MAGNETIZATION IN DOMAINS

The direction of magnetization in the domains is of interest and can be determined by the following techniques:

1. Very fine scratches on the surface of the crystal.
2. The application of mechanical stress.
3. The use of a small permanent magnet probe.

Scratch Technique. When a scratch is made on the crystal surface, normal to the direction of magnetic flux, some of the flux emerges into the air while crossing the scratch. These stray fields attract the particles of magnetite and cause them to collect along the scratch in such a region. If the scratch is made parallel to the direction of the flux, no flux emerges into the air and consequently there will be no concentration of the particles of magnetite along the scratch.

Figure 5 shows patterns obtained on surfaces having very fine scratches. The first pattern is a typical tree pattern and shows very clearly the outline of the domains. The second pattern was obtained on a surface having horizontal and vertical scratches made with a brush of very fine glass fibers. In the branches the vertical scratches are visible, and this shows that the magnetization is horizontal as indicated in the drawing. In other domains the horizontal scratches are visible, and the magnetization is therefore in a vertical direction, as is also shown on the drawing of Figure 5. In some instances it is possible to follow a single scratch across the pattern. In a certain domain the scratch is visible, its appearance indicating that the magnetization is normal to it. In the next domain the scratch is not visible and the magnetization is parallel to it, and so on across the pattern. In this sketch, the heavy lines represent the domain boundaries and the arrows the directions of magnetization in the domains. There are 180-degree boundaries where the magnetization in one domain differs by 180 degrees from that in the adjacent domain, and there are 90-degree boundaries where the magnetization on one side makes an angle of 90 degrees with that on the other side.

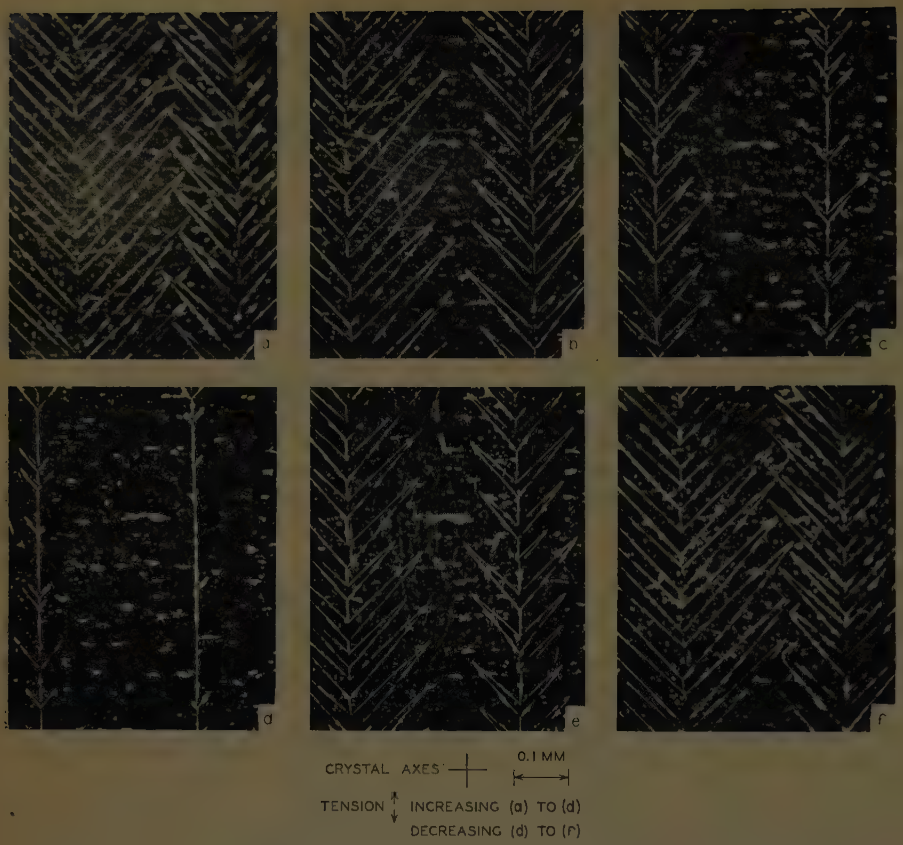

Figure 6. Series of patterns showing effect of increasing and decreasing tension

Use of Mechanical Stress. In a material such as silicon iron, which has positive magnetostriction, the application of tension tends to make the magnetization parallel to the tension. Therefore, the branches which have horizontal magnetization would be expected to disappear if a sufficiently high value of tension were applied in a vertical direction. Figure 6 shows the effect of applying tension. As the tension increases, the branches shrink and practically disappear (Figure 6*d*). Here, the magnetization is almost entirely parallel to the tension. The magnetization vectors in adjacent domains are antiparallel. Notice the elongated splotches; they appear when a concentrated colloid is used and are due to the irregularities produced on the surface by prolonged electrolytic polishing. These irregularities act in much the same manner as the scratches, and the splotches are always normal to the directions of magnetization in the domains. As the tension is decreased the branches reappear and increase in size until a pattern appears that is similar to the original. The

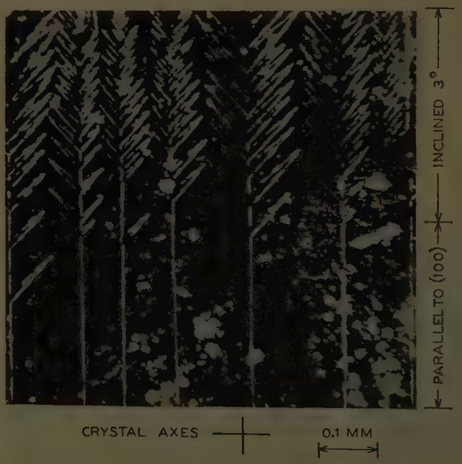

Figure 7. Pattern on a crystal having the lower half parallel to the (100) plane and the upper half inclined three degrees. Tree pattern is detected only on a plane which makes an angle with the plane of easy magnetization

branches are not exactly in their original positions but the pattern is of the same type. This shows that the crystal has not been strained beyond the elastic limit.

PATTERNS ON SURFACES SLIGHTLY INCLINED TO A CUBE PLANE

THE tree pattern occurs when the surface makes an angle of several degrees with the (100) plane, the cube face. Figure 7 shows a pattern obtained on a surface having the lower half parallel to the (100) plane and the upper half making an angle of three degrees with it as indicated on the side of the figure. Notice the tree pattern on the surface which is inclined to the (100) plane.

The tree pattern may be explained as follows. As shown in Figure 8, the flux follows a direction of easy magnetization to the surface and forms positive (north) poles where it emerges. Then if it passes through the air and enters the crystal in the adjacent domain it will form negative (south) poles at the points of entrance. The formation of poles requires a considerable amount of energy. If, instead of passing through the air, part of the flux passes through the material in a direction of easy magnetization, as shown by the solid straight line, less energy will be required. The branches serve to transfer flux from one region to another.

In interpreting these tree patterns it has been shown that there are regions having positive poles and regions having negative poles as indicated in Figure 9. Hence there will be some regions having magnetic fields directed away from the surface and other regions having the fields directed into the surface. When a field is applied normal to the surface it will add to the field already present in some regions and oppose the field in other regions, so that a redistribution of the colloid is to be expected. Notice that in Figure 9*a* the colloid is equally distributed in between the branches. When a field is applied the colloid tends to collect in certain regions and leaves other regions clear, as shown in Figure 9*b*. When the field is reversed the colloid shifts from the regions in which it was concentrated to the regions which were clear. This behavior checks the theory, and in addition enables one to determine the sense of the magnetization vector in the domains.

On considering how the spin orientation changes in the domain boundary between the right-hand branch and the underlying domain in Figure 8, it can be concluded that the spin changes with a right-hand screw relation because this involves a rotation of only 90 degrees while passing through the wall, whereas a left-hand screw relation involves a rotation of 270 degrees and would require three times as much wall energy. The right-hand screw relation forms positive poles at the upper boundary of the branch and negative poles at the lower boundary. The region surrounding the branch has positive poles, so the upper boundary has poles having the same sign as the surrounding region, and the lower boundary has poles having the opposite sign. Consequently, when a field is applied normal to the surface, the upper boundary would be expected to have the same variation in concentration of colloid as the surrounding region, and the lower boundary the opposite variation.

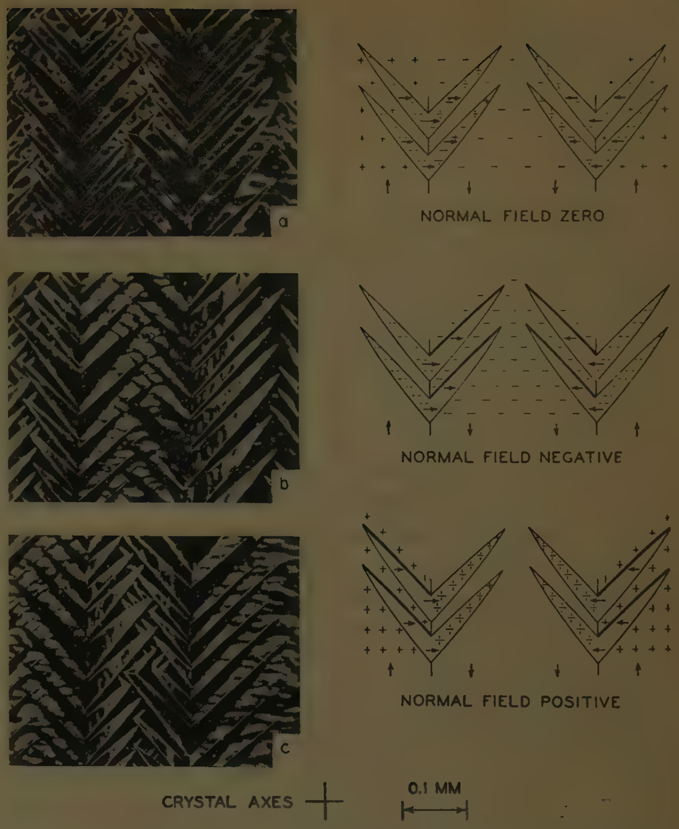

Figure 9. Effect of the applied field on the tree pattern: (*a*) normal field is zero; (*b*) normal field is negative; (*c*) normal field is positive

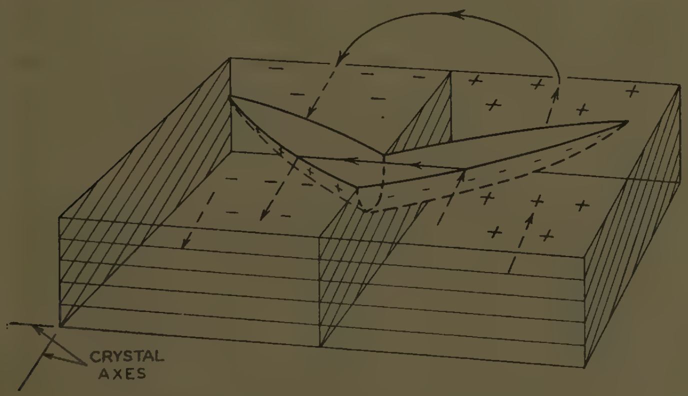

Figure 8. Structure of the tree pattern

HOLLOW PARALLELOGRAM WITH SIDES PARALLEL TO CRYSTAL AXES

IN previous investigations, specimens were cut in the form of hollow parallelograms. They form closed magnetic circuits and can be used to determine the magnetic properties in the different crystallographic directions.

In the following investigations a (100) specimen was used, each side of which was parallel to a direction of easy magnetization. The powder patterns, observed over the entire crystal, showed that the domain structure, except for a few superficial details due to crystal imperfections and irregularities of cross section, was as shown in Figure 10*a*. This is precisely the domain structure that one would expect to form because it represents a minimum energy condition, having the least area of Bloch walls,

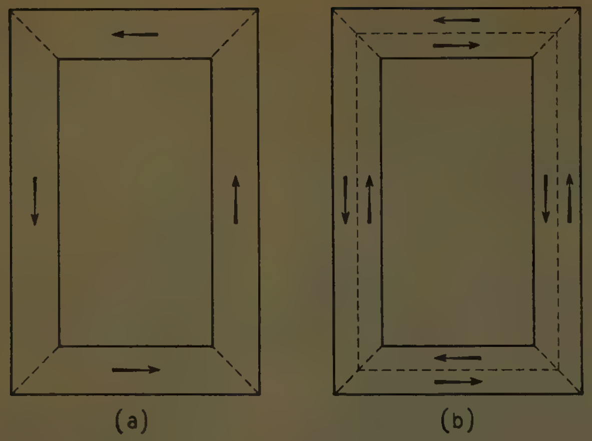

Figure 10. Domain structure of the hollow parallelogram with sides parallel to the crystal axes

(*a*). *After cooling from 1,000 degrees centigrade*
(*b*). *After applying a field*

The dotted lines represent Bloch walls and the arrows the direction of magnetization

and consequently least energy for a structure having no magnetic poles. The rectangular specimen is 1.9 centimeters long, 1.3 centimeters wide, and the cross section is 0.102 by 0.074 centimeter, the latter dimension being normal to the plane of the specimen. Each side of the specimen is a single domain so that two of the domains are 1.9 centimeters long.

This domain arrangement appears to have a net magnetization equal to the saturation. This feature was checked by putting primary and secondary windings around the specimen and then tracing a hysteresis loop with a Cioffi recording fluxmeter. Care was taken not to expose the specimen to magnetic fields previous to this. The results show that the specimen has an initial magnetization of 17,000 gausses after cooling from above the Curie temperature. This value is somewhat low because there is some inaccuracy in measurement of the area on account of the irregularities on the inside of the parallelogram.

The change in the net magnetization of the specimen is observed to be due to the displacement of a 180-degree Bloch wall shown by the drawing of Figure 10*b*. In this arrangement there are eight domains. The flux in the inner four domains of the specimen goes in a clockwise direction, in the outer four domains it goes counterclockwise. The application of a field around the specimen in a clockwise direction displaces the wall so that the four inner domains grow at the expense of the outer four.

Observations were made on a slowly moving boundary. When it moved past small holes or other slight imperfections, appearing on the surface of the crystal, superficial domain structures around these regions united with the wall and formed irregularities in it. A particular example is shown by the drawing of Figure 11*a*. As the main wall continued to move, the secondary walls, extending from the holes to the main wall, became more and more extended and finally broke. Then a new structure formed around the hole and the main wall straightened out (Figure 11*b*).

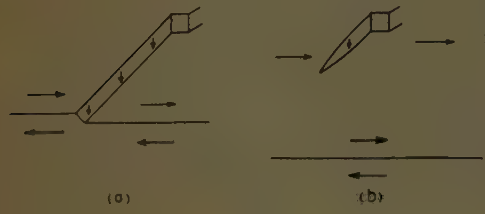

Figure 11. Domain structure around an imperfection in the crystal

(*a*). *Around a square hole connected to a 180-degree Bloch wall*
(*b*). *After breaking the connection*

The Barkhausen effect was heard over a loudspeaker as the boundary was observed to move. It is attributed to these sudden changes in the secondary domain structure around imperfections, and to resulting irregularities in the Bloch wall which occur as the latter moves past imperfections in the crystal.

In this crystal the very simple domain structure formed after cooling through the Curie temperature, and the observed mechanism of change of magnetization which is merely the displacement of a single 180-degree Bloch wall, show the basic features of the domain theory in a very lucid manner. In this case the complete domain structure throughout the crystal was determined, the change in domain structure with an applied field was observed, understood, and correlated directly with the hysteresis loop.

This crystal has a high maximum permeability and a low coercive force, and is the ideal or goal which may be approached by grain-oriented silicon iron. The latter is a polycrystalline material so processed that the crystals tend to line up with a [100] direction along the length of the strip, and make this a direction of easy magnetization. The following table shows a comparison of the two.

	Single Crystal of Si-Fe	Grain-Oriented Si-Fe
Maximum permeability	10^6	3×10^4
Coercive force	0.012	0.15

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Pulse Measuring of Deionization Time

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Equipment for measuring deionization time of gas tubes using the pulse method, which gives greater accuracy of results and permits more precise specification of conditions, has been developed. This article describes test equipment with wide flexibility in the test conditions.

A NECESSARY condition for the initiation of an electric discharge between two electrodes immersed in a gas is that the voltage difference between the electrodes be greater than a critical value called the breakdown voltage. The nature and pressure of the gas and the shape, separation, and nature of the electrodes determine this critical value. When a gas tube breaks down or fires, a positive-ion space charge is formed so that electrons can flow in great quantities without the limitations of mutual repulsion. A self-sustaining discharge in a cold-cathode tube requires, in addition, a positive-ion current sufficiently heavy to provide for electron emission from the negative electrode or cathode.

If the supply voltage for the discharge is suddenly reduced to zero, the positive ions remain in the interelectrode space until they diffuse to the walls or electrodes, since the attractive force of an electrode with an applied voltage is nullified by the surrounding sheath. The electrons in the interelectrode space when the current is extinguished will remain in the space due to the attractive force of the positive ions. Thus, a plasma which consists of equal numbers of electrons and positive ions slowly decays after extinction of current in the external circuit.

If the supply voltage is reapplied quickly, breakdown may occur at a voltage lower than the critical value. This lower value is termed the reignition voltage. If the interval during which the supply voltage has the value of zero is increased to a certain critical value called the deionization time, the reignition voltage will equal the original breakdown voltage. It is not to be inferred that the envelope has been swept clean of ions, but that the ions have moved free of the discharge path so that the reapplied voltage builds up the new discharge without help from the previous discharge.

For purposes of generalization, the reapplied voltage may be the same or opposite in polarity with the voltage which caused the first discharge. The deionization time may have different values for opposite polarities of the reapplied voltage.[1] The deionization time for the reverse polarity is important in gas-rectifier circuits in which the anode voltage (positive electrode during the discharge) is driven negative. The progress of deionization at the time of reapplication of voltage affects the amount of sputtering or gas cleanup in an inverse fashion.[2]

The general concept of deionization can be applied to three-electrode tubes or triodes in which case an additional factor, the effect of the grid and its applied voltage, must be added to the afore-mentioned factors in the determination of the breakdown or critical anode voltage. The usefulness of a thyratron or gas triode stems from the ability of the grid to control the anode breakdown voltage. If a thyratron has not deionized, the grid has no control and, consequently, the grid is useless during this period.

Some of the factors which influence the deionization of a gas tube are well known from the dynamic performance of such tubes. These factors are peak anode current, nature of the gas, gas pressure, dimensions of interelectrode space, grid voltage, and grid resistance. Other factors such as grid current and length of anode pulse are involved, but the lack of quantitative data prevents the formation of a clear picture of the deionization process. It is the purpose of this article to describe test equipment with wide flexibility in the conditions of test which has been developed for measuring deionization time.

Basically, all methods of measuring deionization time involve a means of passing current through a gas tube, a means of interrupting this current, and a means for applying a delayed probe voltage to determine the progress of deionization. Although good results have been obtained with methods using exponential[3–8] or sinusoidal[9–12] wave forms, it appears that methods using square waves[13–17] yield the most accurate results and are subject to most accurate specification. The effective low impedance of gas tubes precludes the use of vacuum tubes for formation of the current pulse. A possible method of current pulse formation is the use of a pulse-forming network, but this method is inflexible in that it does not provide convenient adjustment of pulse duration and impedance. The use of auxiliary gas tubes, however, offers a solution to this problem and they have been incorporated in the test equipment.

In order to eliminate statistical variation and to permit rapid measurements, the method should be repetitive as opposed to a "one-shot" method. The probe voltage pulse should be adjustable in amplitude and independent of the current pulse.

Figure 1 shows the cross section of the thyratrons used for deionization time measurements; Figure 2 is a simplified circuit diagram of the deionization test equipment; Figure 3 gives the waveforms of the voltages and currents and shows the time relationships of events. Conduction is initiated in V_T, the tube under test, by a voltage e_1 applied to its grid. Simultaneously, an auxiliary thyratron V_2 is fired by the same signal e_1. The current i_1 thus established is permitted to flow for a period of, say, 50 microseconds, which is greater than the time necessary to

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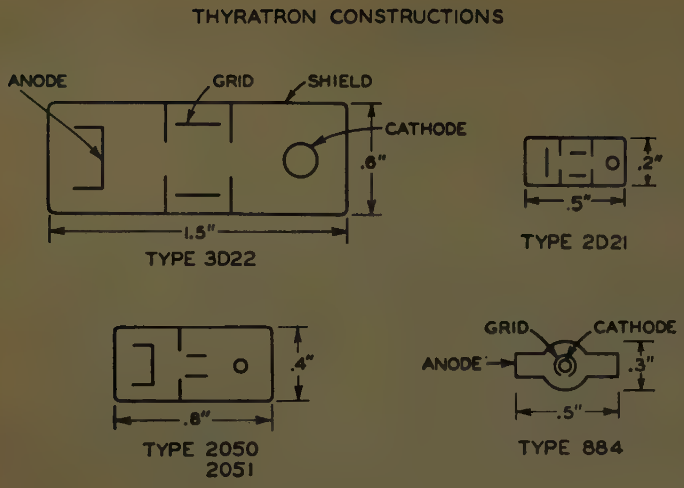

Figure 1. Construction of thyratrons

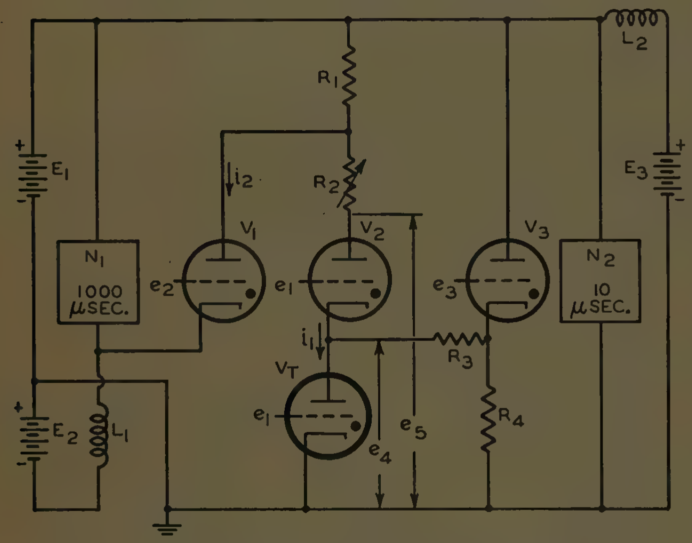

Figure 2. Simplified circuit diagram of test equipment

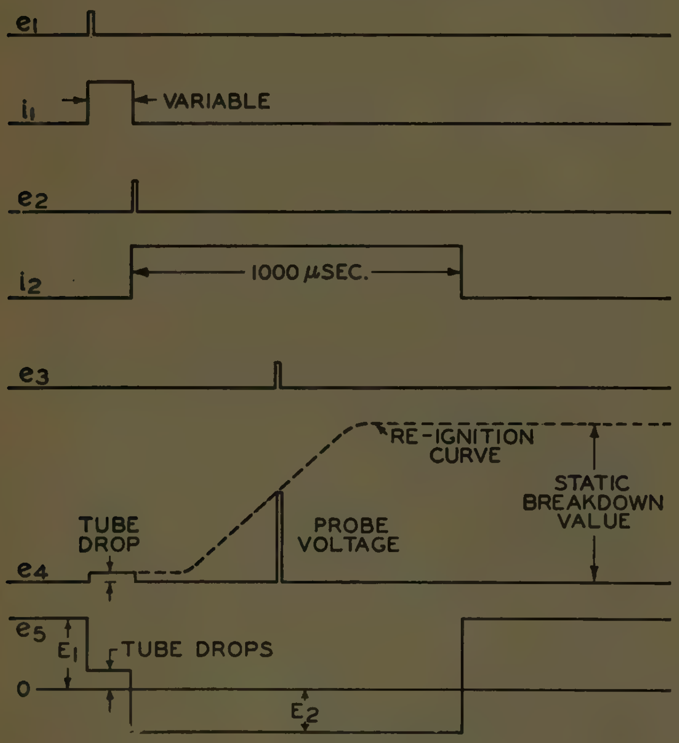

Figure 3 Waveforms of equipment voltages and currents

establish equilibrium. The magnitude of the current pulse through V_T is controlled by varying R_2 and E_1. This current is then extinguished by means of a shutoff circuit consisting of auxiliary thyratron V_1 and its associated network which drops the anode voltage on V_T to ground when the network discharges.

A probe voltage pulse e_4, ten microseconds in duration, obtained from thyratron V_3 and its circuit, is then applied to the anode of V_T during the period following the current pulse to determine the progress of deionization. If the time of application of the probe is long after current extinction, deionization will be complete and the amplitude of the probe voltage must exceed the static breakdown value for reignition. If the probe voltage is applied immediately after current extinction, it need only exceed the tube drop for reignition. At intermediate delays, partial deionization is indicated by the intermediate amplitudes of the probe voltage as shown in Figure 3. Although the cycle is repeated 120 times per second, the oscilloscope must be operated with a fast sweep because the waveforms are of the order of 100 microseconds in duration.

The operation of the shutoff circuit is as follows. The 1,000-microsecond pulse-forming network N_1 charges to a voltage double the sum of voltages E_1 and E_2.[18] At the instant when it is desired to shut off the current through the tube under test, the thyratron V_1 is triggered by pulse e_2. The resulting current i_2 produces[19] a voltage (across R_1) approximately equal to the sum of E_1 and E_2. The spike on the leading edge of the shutoff pulse, shown in Figure 4, serves the purpose of reducing the fall time of the current pulse through the tube under test. A minimum fall time is essential because it is the reference from which all the time measurements are established in this work. The spike is formed when the first inductance of the network N_1 is reduced below the iterative value.[20] Thus, the anodes of V_1 and V_2 are dropped to a voltage E_2 below ground and the anode of V_T is dropped to ground potential. In Figure 3 the wave form e_5 of the anode voltage of thyratron V_2 shows both the effect of the current pulse and the shutoff pulse. The shutoff pulse is 1,000 microseconds in duration which is greater than the deionization time of V_2. At the end of this time the circuit consisting of V_2 and V_T is ready for another cycle. This circuit was designed to be of low impedance so that large test currents (50 amperes) can be drawn at moderate values of E_1 and E_2 (200 volts).

The operation of the probe circuit is as follows. The 10-microsecond pulse-forming network N_2 charges to double the voltage E_3. At the instant when it is desired to test the progress of deionization, thyratron V_3 is triggered by pulse e_3. A pulse of voltage approximately equal to E_3 appears across R_4 (Figure 5). The anode of the tube under test is also driven to the peak value of E_3 unless reignition occurs. By varying the amplitude of E_3 and the time of application of e_3, the reignition curve shown in Figure 3 may be determined. A value of ten microseconds was selected for the probe-pulse duration to permit ready observation on the relatively long time sweeps (100 microseconds) but still be short enough to cut the reignition curve at a precise point. The 10-microsecond duration of the probe pulse is greater than the ionization time of most gas

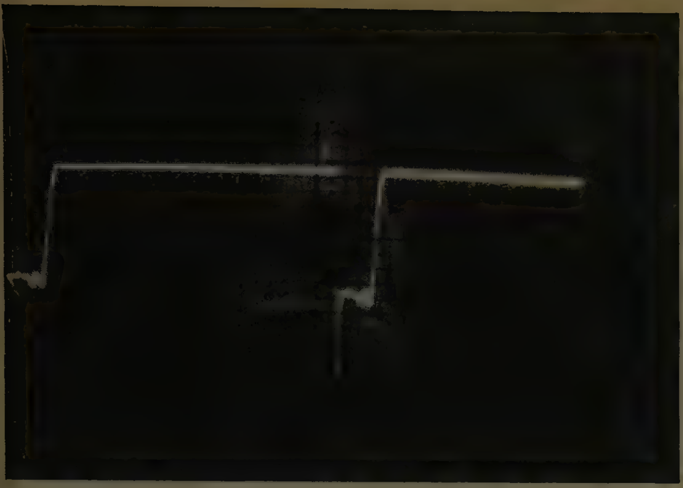

Figure 4. Shutoff pulse for terminating the current pulse through the tube under test

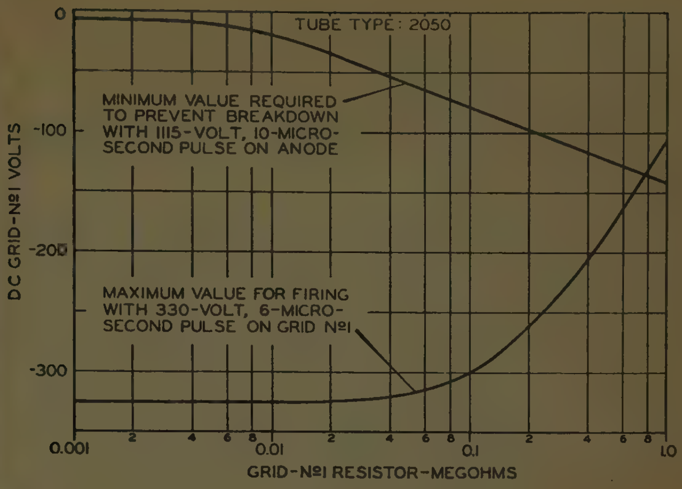

Figure 6. Effect of grid number 1 resistance on tube breakdown

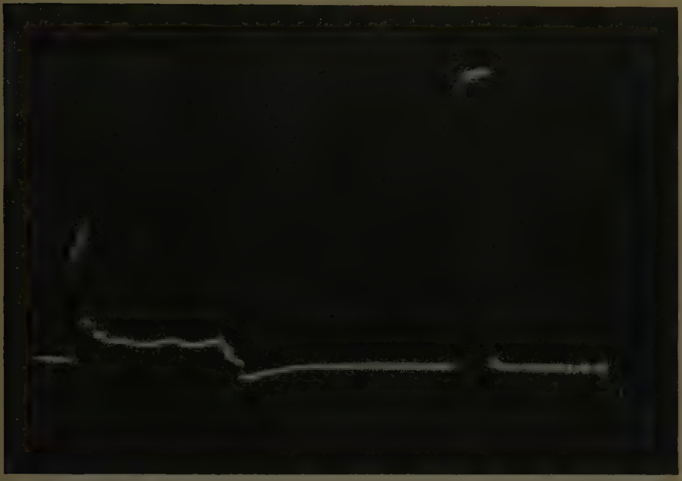

Figure 5. Probe pulse following current pulse observed at anode

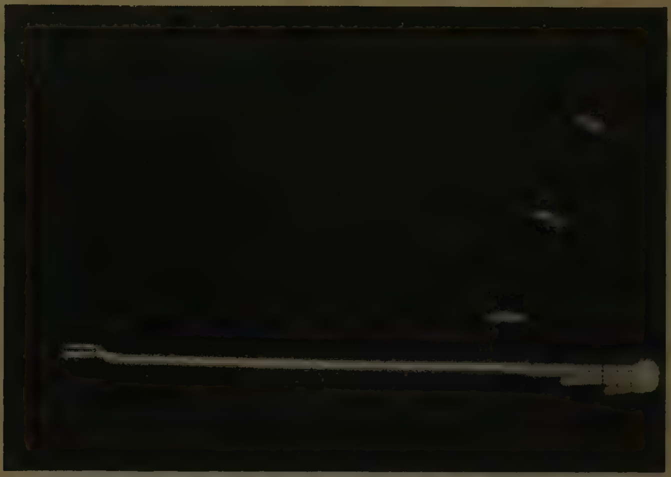

Figure 7. Reignition locus

tubes. The probe-pulse circuit has a low duty cycle (1:800) so that a high-voltage low-current supply can be used for E_3 (5,000 volts maximum, 200 milliamperes).

The use of a 10-microsecond grid pulse requires care to avoid erroneous results due to grid-anode coupling. As a result of the induced grid pulse, a thyratron may break down when a pulse voltage is applied to the anode, whereas the equivalent direct voltage gradually applied will not cause breakdown. The amplitude of the induced grid pulse increases with increasing values of grid resistance. Figure 6 shows the minimum grid bias for preventing breakdown by a given probe voltage as a function of grid resistance.

It has been found that with increasing grid resistance an increasingly larger grid trigger voltage is required; conversely, a decreasingly smaller bias is required for a fixed voltage. Figure 6 also shows how the maximum value of grid bias, which will permit a *2050* to fire when a 330-volt 6-microsecond pulse is applied to the grid, decreases as the value of grid resistance is increased. The explanation of this phenomenon lies in the fact that the grid resistor and the input capacitance act as a voltage divider to reduce the effective amplitude of the 6-microsecond grid trigger.

When the current pulses are short the grid trigger current becomes important. In this equipment the grid trigger is six microseconds long and, therefore, is effectively a lower limit to the useful duration of the anode current pulse. One ampere in the grid circuit contributes as much ionization as one ampere in the anode circuit.

When the grid resistor is small in value, errors due to grid current are avoided by making the grid trigger just large enough to overcome the bias and fire the tube.

Reignition depends upon the amplitude as well as the delay of the probe pulse. Figure 7 is a photographic confirmation of this fact. The tube drop due to the current pulse may be seen as a slight rise at the left of the base line. Triple exposures were made to record the probe pulse at the minimum delay before reignition at three amplitudes of probe voltage. A curve drawn through the leading top edge of the probe pulses would give the reignition locus.

TEST RESULTS

Current-Pulse Duration. Previous investigators have used current pulses with durations in the order of one microsecond to measure deionization time. This procedure was questioned as to whether complete equilibrium had been obtained and as to whether there were results to justify this expedient. The equipment described herein was built so that the duration of the pulse current could be varied in

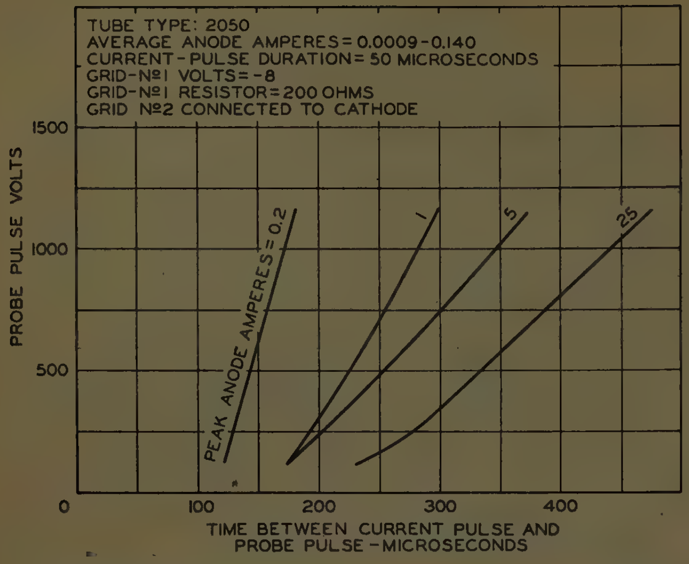

Figure 8. Effect of peak current on deionization

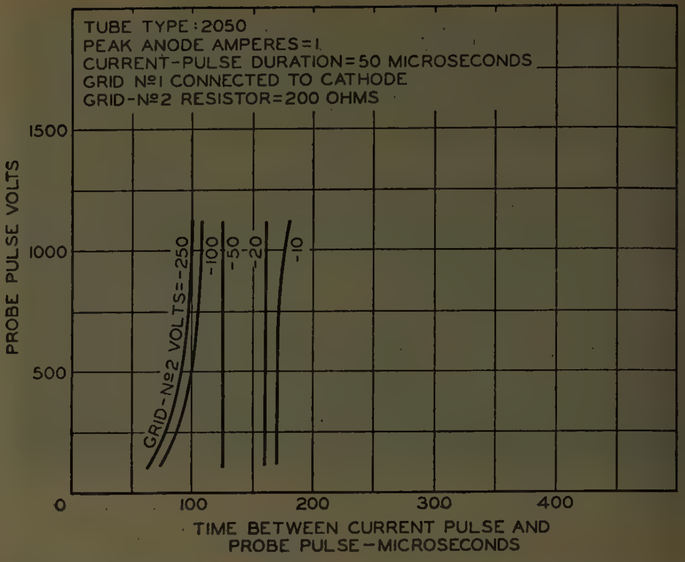

Figure 11. Effect of grid number 2 voltage on deionization

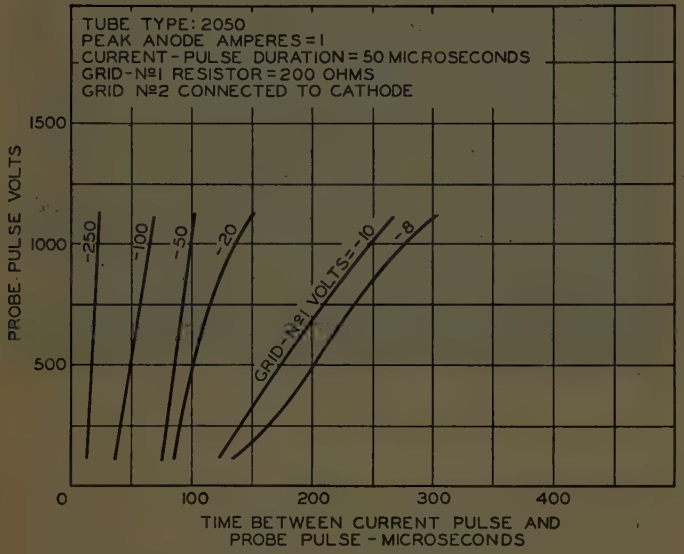

Figure 9. Effect of grid number 1 voltage on deionization

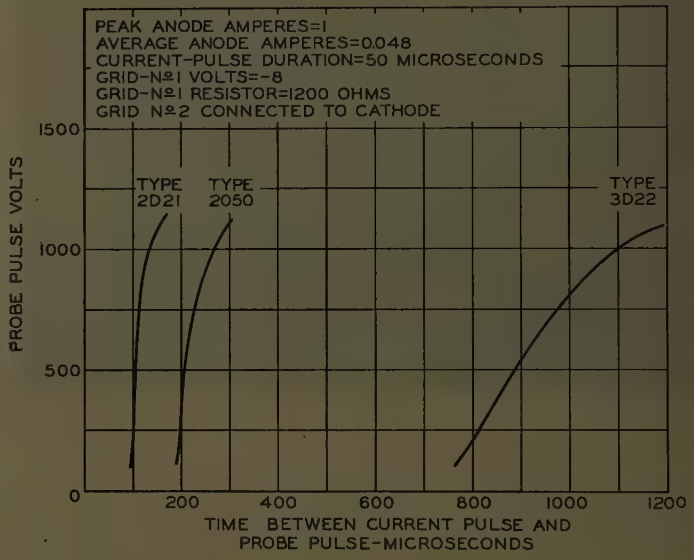

Figure 12. Effect of tube dimensions on deionization

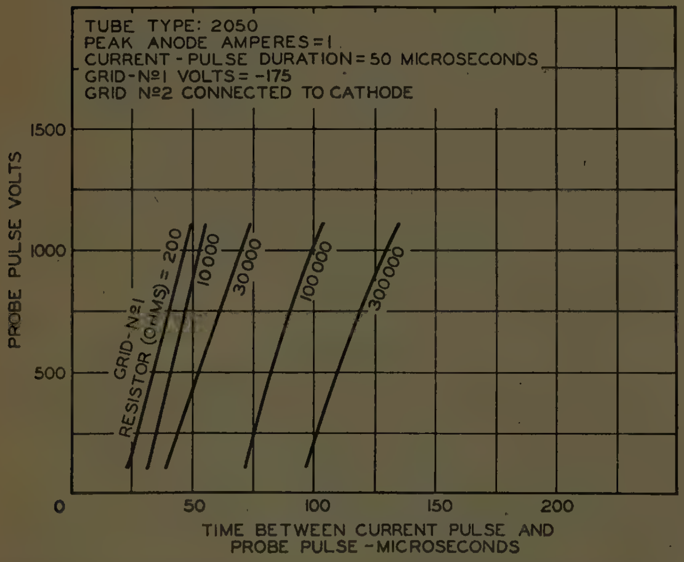

Figure 10. Effect of grid number 2 resistance on deionization

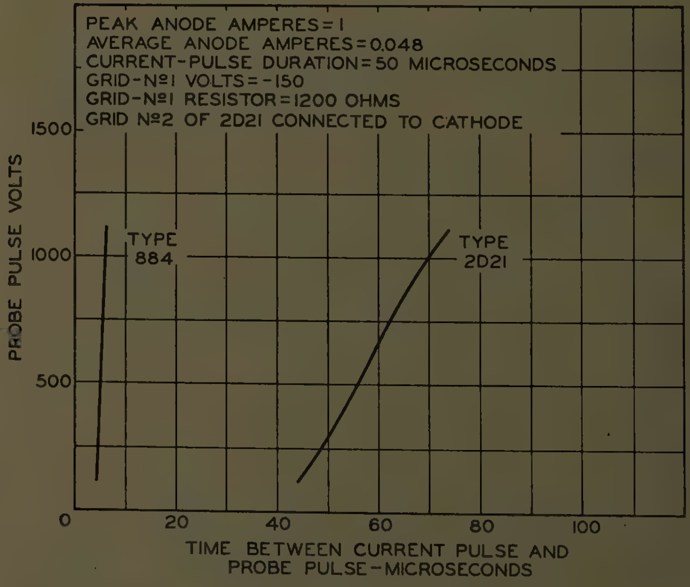

Figure 13. Comparison of tubes of short deionization time

Table I. Effect of Current Pulse Duration Variation

	Deionization Time, Microseconds					
	Duration of the Pulse in Microseconds					
Probe Pulse Volts	100	50	25	12	6	1.5
1,100	115	110	110	118	134	119
900	108	103	104	106	110	109
680	102	98	101	101	103	104
450	96	96	96	96	94	99
230	93	90	89	92	91	96
110	89	86	86	91	91	93

order to check this point. Table I shows the effect of varying the duration of the current pulse from 1.5 to 100 microseconds. The divergences of the data are within the probable error of measurement and show that equilibrium is established in 1.5 microseconds in the type *2050*. The lower limits of current-pulse duration for the standard circuit of this equipment was six microseconds. The 1.5-microsecond pulse was obtained by use of an auxiliary network. For most of the data herein presented 50 microseconds was selected as the current-pulse duration.

Peak Current. Figure 8 shows the effect of peak current on the reignition curve. These curves display the typical shape of the reignition characteristic: a slow rise followed by a linear portion and then a tangential approach to the static firing value. Five-fold increases in peak current give about equal increments in deionization time; deionization time is a logarithmic function of current.

Grid Parameters. Figure 9 shows the effect of increasing the negative grid voltage at constant grid resistance; Figure 10 shows the effect of decreasing the grid resistance at constant grid bias. Both changes shorten deionization time. Figure 11 shows the effect of applying the bias to the shield grid instead of the control grid. Data for Figures 9 and 11 were taken on the same tube under the same conditions. As a deionizing agent the shield grid seems to be more effective at low bias and less effective at high bias than the control grid.

Effect of Dimensions. Types *2D21*, *2050*, and *3D22* are all shield-grid thyratrons of similar construction (see Figure 1) but increasing size filled with xenon at essentially the same pressure. The results of testing all three types for deionization time under the same conditions are shown in Figure 12. The deionization times measured at 500 volts on the anode are nearly proportional to the cross-sectional area of the tube cage as the following tabulation shows. The measurements were made under the conditions given in Figure 12.

Type	Cross Section, Square Inches	Deionization Time Microseconds
2D21	0.115	106
2050	0.284	206
3D22	0.818	885

The *884* is an argon-filled triode thyratron of still smaller dimensions but of different construction. Its reignition characteristic is compared with that of the *2D21* in Figure 13. The grid bias used was −150 volts which is necessary to prevent the *884* from firing when the 1,115-volt probe is applied. Note that the time scale is expanded in this figure. The smaller dimensions account for the shorter deionization time of the *884*.

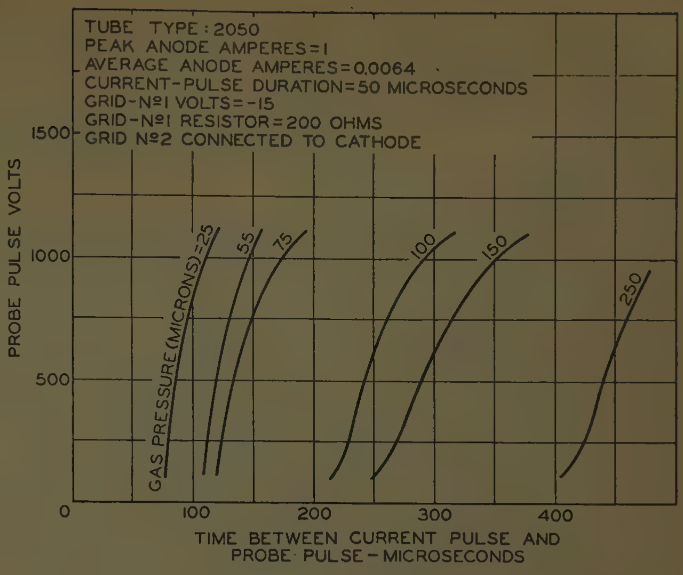

Figure 14. Effect of gas pressure on deionization

Gas Pressure. It has long been a problem to determine the pressure within a gas tube after sealing. The electrical characteristics are relatively insensitive to pressure changes but deionization is very sensitive as Figure 14 shows. Special tube types identical with type *2050* except for gas pressure were tested with pressures from 25 to 250 microns.

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Use of the Current Transductor in the Aluminum Industry

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The current transductor is a device used for the measurement of large quantities of direct current. It has many advantages over the d-c ammeter shunt which is usually used in d-c power circuits; by use of the transductor the secondary circuit is insulated from the primary source and all dangers of a nonisolated main circuit are eliminated.

THE CURRENT transductor is one of the great family of apparatus known variously as magnetic amplifiers, saturable core reactors, or transductors. These devices are a-c inductors, whose effective inductance can be changed by superimposing a d-c magnetomotive force. The current transductor is a transductor specially designed and calibrated so that the alternating current flowing in the a-c circuit is a direct measure of the direct current which is flowing in the d-c circuit. The transductor is meant to be used for the measurement of the direct current.

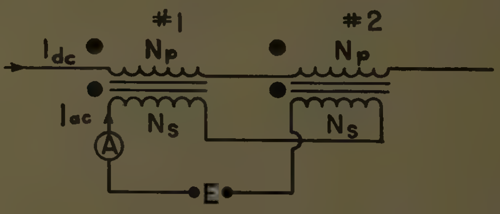
The current transductor when put in comparison with the conventional d-c ammeter shunt which is commonly used in d-c power circuits, has two outstanding advantages.

First, the secondary circuit is insulated from the measured source. With the d-c shunt, the voltage of the main circuit appears at the instruments on the switchboard. With the transductor, the secondary circuit is fully insulated and may be grounded. The importance of isolation of the main or the primary circuit is very well understood in a-c practice.

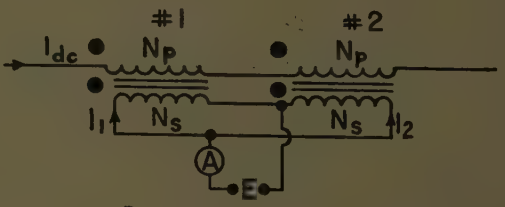
Isolation prevents damage to the primary circuit from any possible grounds in the secondary circuit. Insulation prevents damage to any of the instruments or injury to any of the operating personnel. It permits instruments to be installed at any convenient location without regard to primary voltage. To realize the full benefit of this advantage, the secondary circuit of the transductor should, of course, be grounded.

Second, convenience and economy is afforded through the use of any number of instruments. With the d-c shunt, the value of the lead resistance to the meters is critical, and in the lower current ratings the number of meters that can be connected to one shunt is limited. As the current transductor has characteristics similar to the regular a-c transformer, the resistance of the meter or leads is not critical. The current transductor can be designed to carry as many meters as is desired, even in the low-current range. In addition to his freedom to add additional instruments, relays, or other current-operated devices as he may desire, the operator has the choice of all the wide range of a-c devices which are to be used in the secondary a-c circuit of the current transductor.

A current transductor resembles, physically, a double-secondary a-c transformer. For purposes of analysis, the current transductor may be most easily visualized by thinking of it as two conventional a-c transformers with their primaries connected in series. See Figure 1. The secondary windings may be connected in series or in parallel as is shown in the figure, but in both cases one of the secondary windings must be connected in reverse polarity to that of the other winding. The secondary windings are then excited from a source of alternating voltage and an ammeter or other burden is put in the a-c line. For purposes of this analysis, it is assumed that the voltage drop across this burden (the ammeter) is small compared to the source voltage.



(a) SERIES



(b) PARALLEL

Figure 1. Connections for current transductors show that they resemble two conventional a-c transformers with the primaries connected in series. Secondaries may be connected series or parallel as long as they are connected with reverse polarity

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Essential substance of paper 50-64, "The Theory of the Current Transductor and Its Application in the Aluminum Industry," recommended by the AIEE Committees on Instruments and Measurements and Transformers and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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A number of current transductors have been used in aluminum plants. It is customary in aluminum reduction plants to operate several d-c machines in parallel on a common bus to produce the relatively large amounts of current required for aluminum production. The central switchboard from which these machines are operated usually contain for each machine a millivoltmeter operated from a shunt in the d-c leads and calibrated in machine amperes. The leads from these shunts are often long and may require special meter calibration. The leads operate at bus voltage and are difficult to protect satisfactorily by fuses or other devices. Therefore, they produce electrica hazards in the switchboard. Some fires have resulted.

In the hope of eliminating some of these disadvantages, an aluminum reduction plant has recently been equipped with a large number of transductors rated 2,000 amperes d-c to one ampere a-c. These transductors were made with the a-c coils in series. These are in the d-c machine leads, and each operates two a-c ammeters in series. One is located near each machine, and the other is located several hundred feet distant at a central control switchboard. At this switchboard is located a 110-volt 60-cycle source large enough in capacity to supply 40 transductors. One side of this source is common to all the instruments, and the other is run as a bus the length of the station and is connected to each transductor. With this circuit arrangement, it can be seen that only one wire is required from each machine to the central board for load indication. This lead is only at 110 volts and can be adequately fused. Especially calibrated dials were used on the instruments which were made from test curves on the first transductor. All transductors and all instruments are alike. The transductor is constructed similar to a current transformer and should be stable over a number of years.

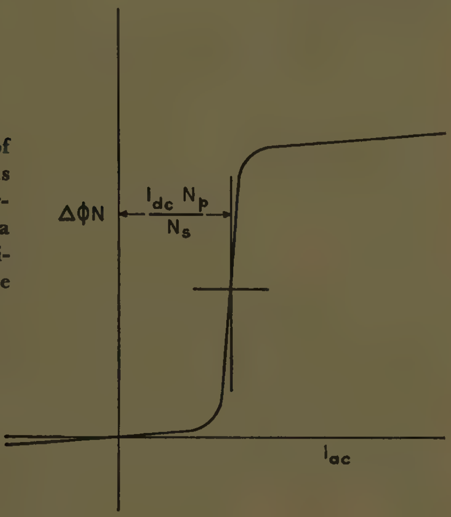

Figure 2. Change of a-c coil flux linkages as a function of the alternating current for a particular value of direct current in the primary winding

A second application in the aluminum industry is in the main d-c circuit to the cell lines. Here it is required to measure currents often as high as 50,000 amperes with the greatest possible accuracy. The shunts for these circuits are mammoth devices weighing several hundred pounds. Their resistance is so low that it requires very special equipment to calibrate them to the required accuracy. The millivolt output must be kept low or the power consumption and heating will be prohibitive. This latter objection makes it difficult to provide the necessary instruments at remote locations required by the operating personnel. In some cases it has been necessary to use shunt leads as large as 500,000 circular mils to operate meters at the distances required.

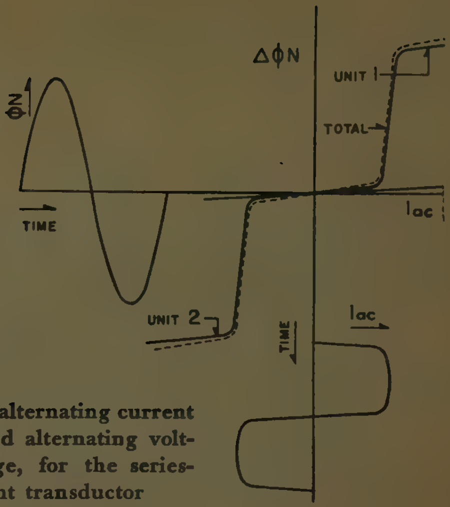

Figure 3. Required alternating current for sinusoidal applied alternating voltage and flux linkage, for the series-connected current transductor

With these objections in mind, these cell-line circuits are being equipped with transductors nominally rated 75,000 amperes d-c to 37.5 amperes a-c for an average flow of about 50,000 amperes. These units also had the a-c coils connected in series. The switchboard instruments in this case are 5-ampere iron-vane instruments specially calibrated and operated from a current transformer in the 37.5-ampere 440-volt exciting circuit. Several remote indicating and recording instruments are used which constitute a circuit some 3,000 feet long.

The ability to insulate instrument circuits is very important. The ease of installation of the transductor, the wide choice of instruments available, and the possibility of locating these instruments at any point without thought to lead length are further important advantages. The 16.5 kva of exciting power may be considered a disadvantage; however, the actual watts in excitation are below 1,000 and are less than in a large shunt.

For the series connection the alternating current in the secondary can be found by the following method. Referring to Figure 2, the change in the flux linkages linking the a-c secondary coil of unit *2* is plotted as a function of the secondary current for a particular value of direct-current in the primary winding. The zero point for the flux linkages is the value of flux linkages due only to the direct current with no alternating current flowing. In Figure 3, the curve from Figure 2 is replotted for unit *2*, and also the similar curve for unit *1*. Since the two units have identical characteristics, these two curves will be symmetrical with respect to the origin. Also, plotted on Figure 3 is the sum of the curves for units *1* and *2*. This curve then gives the total change in flux linkages in the secondary coils as a function of the alternating secondary current. It will be assumed the applied voltage is sinusoidal, and that the series voltage drop across the burden is negligible. It can then be shown that the necessary flux linkages in the secondary coils are sinusoidal.

$$e=\sqrt{2}E \sin \omega t$$

$$\phi N=\frac{\sqrt{2}E\,10^8}{\omega} \cos \omega t \qquad (1)$$

From Figure 3, the alternating current necessary for sinusoidal flux linkages developed in the units is shown. The alternating current that flows is essentially a series of positive and negative polarity rectangular pulses. The maximum value of the alternating current is nearly the direct current times the ratio of the d-c turns to a-c turns. Also from Figure 3, the shape of the alternating voltage wave across each secondary can be determined. When the alternating current is positive, the core of unit *1* is almost completely saturated. There is very little flux change in unit *1*, and consequently it develops very little voltage. Hence unit *2* must develop most of the voltage when the alternating current is positive. As the flux change in *2* is from zero to a maximum and back to zero, the voltage induced starts from a maximum to zero and to a minimum.

The secondary alternating current is relatively insensitive to changes in alternating voltage. This is readily seen from Figure 3. If the alternating voltage and hence the a-c flux, is decreased, it will take a little longer for the alternating current to reach its maximum value, but it will reach the same maximum value. The average alternating current will decrease some, but not nearly in proportion to the voltage decrease. In a typical design, a 5 per cent change in voltage results in less than 1 per cent change in current. This is so slight that no precautions need be taken usually for voltage variations. The effect on the secondary current of changing the burden is about the same as that of changing the voltage. The secondary current does not decrease nearly as rapidly as the burden voltage drop increases.

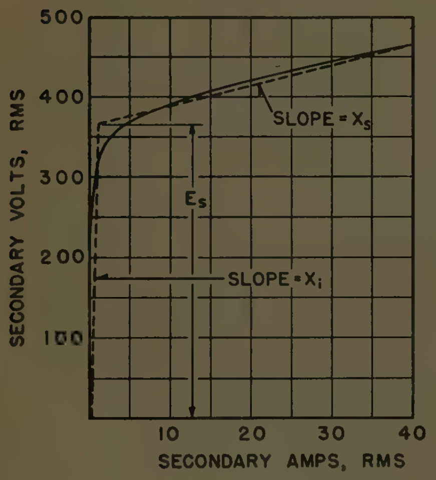

Figure 4. Excitation curve for a current transductor rated 75,000 amperes d-c to 37.5 amperes a-c at 60 cycles. Curve is for one core. The approximate 2-line saturation curve is shown dotted

$X_i=400$ *ohms*
$X_s=2.4$ *ohms*
$E_s=365$ *volts*

Analysis[1] shows that if the equation of the saturation curve for the core material is known, it is possible to solve for the secondary current in terms of the primary current and the constants of the transductor. The simplest curve to choose is a 2-straight-line saturation curve, such as is shown in Figure 4. This curve is for one core of the unit.

Effective values of initial slope X_i and saturated slope X_s are chosen, as well as a value for E_s, the saturation voltage. These should be chosen so as to take into consideration the rounded knee of the actual saturation curve. For the series connection, the average value of the alternating current will be approximately

$$I_{\text{avg}}=\frac{N_pI_{\text{dc}}}{N_s}\left[1-0.45\frac{X_s}{E}\frac{N_pI_{\text{dc}}}{N_s}\right]-\frac{\sqrt{2}E_s}{X_i}+0.9\frac{E}{X_i} \qquad (2)$$

The rms value of the current for the series connection is

$$I_{\text{rms}}=\frac{N_pI_{\text{dc}}}{N_s}\left[1-0.6\frac{X_s}{E}\frac{N_pI_{\text{dc}}}{N_s}\right]^{1/2}-\frac{\sqrt{2}E_s}{X_i}+0.9\frac{E}{X_i} \qquad (3)$$

N_p is the primary d-c turns; N_s is the secondary turns on each core; I_{dc} is primary direct current; and E is the secondary excitation voltage. These formulas are based on the 2-line curve of Figure 4, and the actual current is somewhat different. The formulas are close enough for practical purposes, however, and give an excellent idea of the effect of changes in the various constants.

The parallel circuit connection may be analyzed as follows. Each of the units of the parallel connection of Figure 1 operate independently, as each is connected directly, except for the meter drop, to the alternating voltage; and each has a definite primary direct current. The problem resolves itself into finding the alternating current flowing in one winding of a transformer when there is a pure direct current flowing in another.

The secondary current can be determined graphically as follows. Figure 5 shows a saturation curve for one of the cores that is ideal and has no exciting current up nearly to the saturation point. For the following graphical method the actual saturation curve could be used just as well if desired. The current I_t is the total current, primary plus secondary, on the secondary-turns basis. Since there is a d-c magnetomotive force on the core, there must be a d-c component in the flux density, although its magnitude cannot be determined directly. As the applied voltage is sinusoidal, the flux density in the core must also vary sinusoidally, neglecting the resistance of the a-c winding. If the value of the d-c flux in Figure 5 were zero, the total current required for sinusoidal flux variation would have no d-c component. If the d-c flux is not zero, there will be a d-c component in the total current. It is fundamental that there can be no direct current flowing in an a-c circuit consisting of a constant resistance and a constant or variable reactance supplied from an a-c supply, after the transient currents have subsided. It follows that the d-c component of the current in the total current, when there is a d-c component in the flux, can only be supplied from the d-c winding. The d-c component of flux adjusts itself until the d-c component in the total current is equal to the direct current, all referred to a-c turns basis. The process of analysis is indirect; a value of d-c flux must be found by trial which gives the known value of direct current. In Figure 5, the d-c component of the current is shown as the dot-dash line, and as marked on the figure must be equal to $I_{\text{dc}}N_p/N_s$. If the dot-dash line is considered the zero line, the current as shown in Figure 5 will

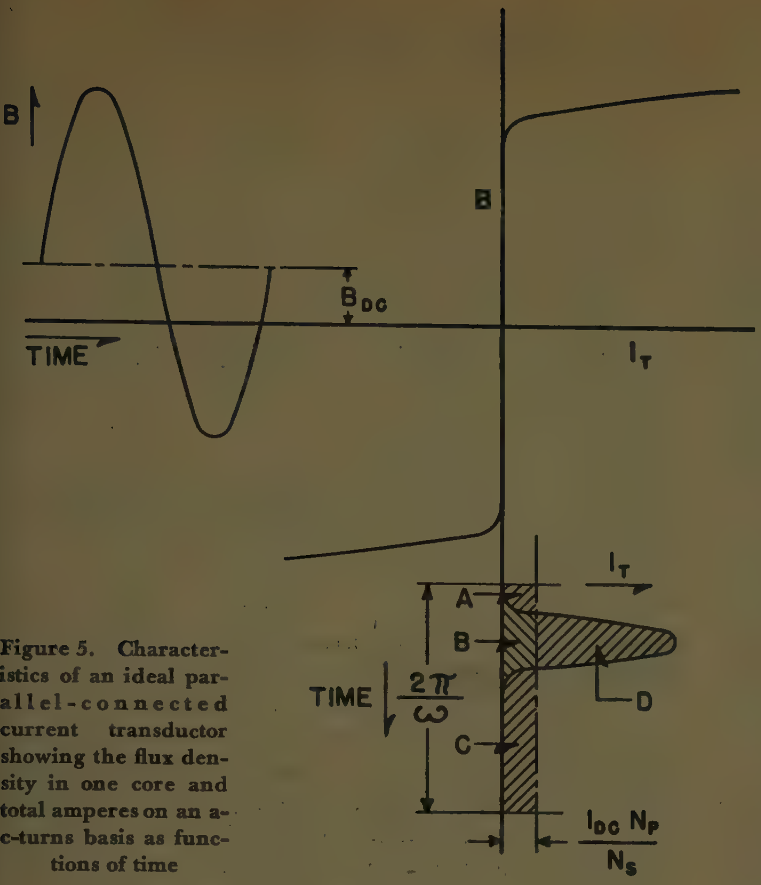

Figure 5. Characteristics of an ideal parallel-connected current transductor showing the flux density in one core and total amperes on an a-c-turns basis as functions of time

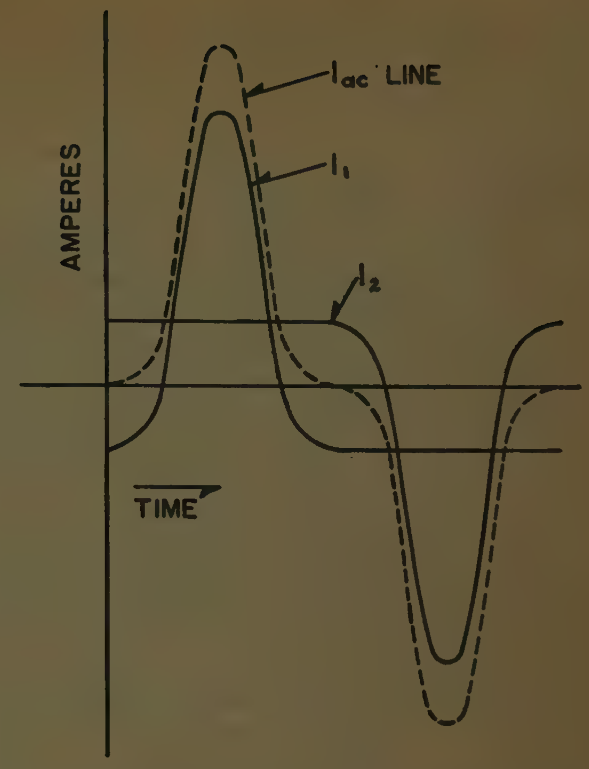

Figure 6. Alternating current in each section and alternating line current for an ideal parallel-connected current transductor

be the alternating current flowing in one secondary, for the alternating current would be instantaneously the total current minus $I_{dc}N_p/N_s$. The current for the other secondary could be determined in a similar manner. It would be the negative of the current in the first secondary, with 180 degrees phase displacement between the two. The line current would be the sum of the two secondary currents.

This method is quite general, but if the saturation curve is limited to the ideal curve shown in Figure 5, some very revealing facts may be deduced regarding the basic operation of the circuit. Referring to Figure 5, the initial part of the saturation curve is assumed vertical up to a value of flux density equal to or greater than B_{dc}. This will result in the total current being zero for a half cycle or more. As was explained previously, the average value of the total current required must be $I_{dc}N_p/N_s$, shown as the dot-dash line on Figure 5. Referring to the areas shown on Figure 5, it must be true:

$$A+B+C=I_{dc}\frac{N_p}{N_s}\frac{2\pi}{\omega} \tag{4}$$

$$A+C=D \tag{5}$$

Therefore,

$$B+D=I_{dc}\frac{N_p}{N_s}\frac{2\pi}{\omega} \tag{6}$$

The alternating current flowing in each secondary is the current shown in Figure 5 with the dot-dash line as the zero line.

In Figure 6 is shown the current flowing in each secondary winding, and the line current, the sum of the two. It will be noted that the line current is identical in shape to the total current in Figure 5. This is because the opposite secondary restores the d-c component of current lost in the secondary considered. It should be noted that this is only true if the total current in Figure 5 is zero for at least a half cycle.

The area under the line a-c wave for a half cycle is $B+D$. Therefore, the average value of the line alternating current for a half cycle is:

$$I_{ac-avg}=\frac{B+D}{\pi/\omega}=2I_{dc}N_p/N_s \tag{7}$$

It is evident then that the average value of the alternating line current is directly related to the direct current, regardless of the slope of the saturation curve above the knee. If the slope is small, the pulse of alternating current will be small in width and high in peak value. This will result in the line alternating current having a higher rms value, but the average value will still remain the same. If the slope above the knee is large, the pulse of the alternating current will be wider in width, and the rms value of the line current will be smaller.

The average secondary line current can be determined analytically for a 2-straight-line saturation curve similar to Figure 4. This curve is for just one of the cores. From such a curve, effective values of the initial slope X_t, the saturated slope X_s, and the saturation voltage E_s are chosen. The average line current for the parallel connection is

$$I_{acl}=\frac{2N_pI_{dc}}{N_s}-\frac{2}{X_t}\left[\sqrt{2}E_s-2.32E+2.5X_s^{2/3}\left(\frac{N_pI_{dc}}{N_s}\right)^{2/3}E^{1/3}\right] \tag{8}$$

This expression is valid only if

$$I_{dc} \leq 0.583 \frac{N_s E}{N_p X_s} \qquad (9)$$

under which condition the alternating line current meets the requirement of having zero slope at current zero. See Figure 6.

In the 75,000-to-37.5-ampere current transductor that is used for measuring current in an aluminum-reduction line, each core on the unit has 14 coils; the primary bus opening is 11 by 34 inches, and the unit is series-connected. The secondary coils may seem to be spaced unnecessarily far from the primary bar, but the longer the length of the core, the thinner the coils will be. This will result in a smaller air-cored reactance, and hence saturated reactance X_s, and consequently better performance.

The excitation curve for both cores on this unit is shown in Figure 4. From this curve, values of X_i, X_s, and E_s can be determined. In Table I are listed the test and calculated values of average and rms alternating current. The average current was read by a rectifier voltmeter reading the voltage across a known resistance, and the rms current was read by a dynamometer ammeter.

Figure 7 is an oscillogram of a test made on the 75,000-ampere transductor. This oscillogram shows the alternating voltage on each of the a-c coils, the direct current, and the alternating current. The test was made at about 50 per cent direct current. The oscillogram shows the transient response of the transductor. The alternating current follows the direct current very closely; the transient response of the series-connected current transductor is very excellent.

The series connection of the a-c coils is the simpler circuit, but there may be cases in which the use of the parallel connection is more desirable. If the d-c circuit has very low impedance, appreciable alternating current may circulate if the series connection is used. This will throw off the calibration of the instrument, although the variation is not a major one. With the parallel connection there is practically no alternating voltage across the d-c coil, and a parallel-connected transductor would be unaffected by the impedance of the d-c circuit. In other circuits, it is possible that the circuit could not tolerate the alternating voltage developed across the d-c coil. With these, the parallel connection may be more desirable.

When the direct current is small, with the series connection, there are times during a cycle when neither core is saturated. If the direct current should change rapidly at these low values of direct current, high peak voltages may be induced across the a-c coils. This does not occur at higher values of direct current, as under this condition one of the cores is always saturated, and the peak voltage induced in the other coil is short circuited through the saturated coil and the a-c supply.

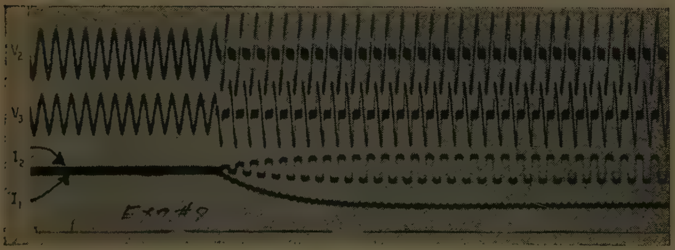

Figure 7. Oscillograms of tests made on 75,000-ampere current transductor at 50 per cent current

I_1 is the direct current, and I_2 is the alternating current
V_2 and V_3 are the voltages across the coils on each core

Table I. Test and Calculated Values of Alternating Current for a Current Transductor With Series Connection

Primary Current, D-c Amperes	Excitation, Volts	Burden Resistance, Ohms	Average Current, Amperes		RMS Current, Amperes	
			Test	Calculated	Test	Calculated
100,000	440	0.375			44.7	45.4
75,000	440	0			34.6	34.8
75,000	480	0.375			34.9	35.0
75,000	440	0.375	33.4	33.7	34.7	34.8
75,000	400	0.375			34.5	34.5
75,000	300	0.375			33.4	33.3
75,000	440	0.75			34.7	34.8
56,250	440	0.375	25.2	25.9	26.0	26.5
46,700	440	0.375			21.8	22.1
37,500	440	0.375	17.2	17.6	17.8	17.9
18,750	440	0.375	8.5	8.9	8.7	8.9
7,500	440	0.375	3.5	3.4	4.0	3.4

Primary current = 75,000 amperes d-c
Rated secondary current = 37.5 amperes a-c
Secondary excitation voltage = 440 volts at 60 cycles
Series connected, $N_p = 1$ turn; $N_s = 2{,}000$ turns; $E_s = 365$ volts; $X_i = 400$ ohms; $X_s = 2.4$ ohms
Secondary resistance = 0.88 ohms
Rated secondary burden = 0.75 ohms

Another application that might dictate the use of the series-connected current transductor is one where it is desired that the transient response will be very rapid. With the series connection, a ripple frequency in the direct current up to six times the excitation frequency should be faithfully reproduced in the alternating current. When the direct current is suddenly applied, the alternating current will follow the direct current faithfully as is shown in Figure 7. With the parallel connection, a sudden change in the direct current causes an equal and opposite current to circulate between the a-c coils. Until this current decays, there is no increase in the effective d-c magnetomotive force on the cores. It will require one or two cycles on a 60-cycle basis for the circulating current through the a-c coils to decay. For use with indicating instruments, this is sufficiently rapid, but for relaying, it may not be.

CONCLUSIONS

The current transductor, a device with many of the characteristics of the current transformer, is a practical piece of apparatus for metering direct currents. It has a secondary a-c output that is proportional to the d-c input and that is little affected by the burden in the metering circuit or the voltage or frequency of the excitation voltage. The secondary metering circuit is electrically isolated from the d-c circuit that is being metered. The time of response is very rapid with the series-connected current transductor in the order of a fraction of a cycle. With the parallel-connected transductor, the time is in the order of one to two cycles.

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Sections

Name	District	Organized	Chairman	Secretary	Secretary's Address
Akron	2	Aug. 12, '20	J. R. Dorsey	J. C. Hall	1374 Roslyn Ave., Akron 20, Ohio
Alabama	4	May 22, '29	M. M. Collins	J. F. Webb	Alabama Power Co., 600 No. 18th St., Birmingham 2, Ala.
Arizona	8	Mar. 22, '41	Americo Lazzari	J. E. Redmond	Drawer 869, Phoenix, Ariz.
Arkansas	7	Apr. 23, '47	M. E. Crippen	C. E. Hutchison	707 Boyle Building, Little Rock, Ark.
Arrowhead	5	Apr. 23, '47	Jennings Johnson	Harvey Sargent	Superior Water, Light & Power Co., Superior, Wis.
Beaumont	7	June 27, '45	H. E. Mortimer	W. T. Evans	1070 Central Drive, Beaumont, Tex.
Boston	1	Feb. 13, '03	L. F. Cleveland	L. J. Weed	Boston Edison Co., 182 Tremont St., Boston 11, Mass.
Canton	2	Nov. 5, '47	R. V. Kelch	D. L. Westhoefer	Hilscher-Clarke Elec. Co., 519—4th St., N. W., Canton 3, Ohio
Central Indiana	5	Jan. 12, '12	J. W. Sears	C. A. Wilson	3541 No. Wallace St., Indianapolis 18, Ind.
Chicago	5	1893	E. L. Michelson	W. M. Ballenger	General Electric Co., 840 So. Canal St., Chicago 80, Ill.
Cincinnati	2	June 30, '20	W. H. McNutt	W. W. Gulden	3272 Daytona Ave., Cincinnati 11, Ohio
Cleveland	2	Sept. 27, '07	W. H. Chase	L. E. Knapp	Westinghouse Electric Corp., 1370 Ontario St., Cleveland, Ohio
Columbus	2	Mar. 17, '22	R. L. Merrill	Floyd Knapp	Ohio Bell Tel. Co., 42 East Gay St., Columbus 15, Ohio
Connecticut	1	Apr. 16, '21	H. M. Turner	F. W. Buck	United Illuminating Co., 80 Temple St., New Haven 6, Conn.
Dayton	2	June 9, '43	J. M. Rodgers	R. L. Dingle	4315 Corinth Blvd., Dayton 10, Ohio
Denver	6	May 18, '15	W. A. Morgan	H. F. Gidlund	Pub. Serv. Co. of Colo., P.O. Box 840, Denver 1, Colo.
East Tennessee	4	Sept. 2, '36	R. M. Alspaugh	J. W. Crabtree	626 South Gay St., Knoxville 11, Tenn.
Erie	2	Jan. 11, '18	K. H. Ishler	G. H. Ramandanes	1719 French St., Erie, Pa.
Florida	4	Jan. 28, '31	Fred H. Pumphrey	John W. Wilson	Box 2155, University Station, Gainesville, Fla.
Fort Wayne	5	Aug. 14, '08	R. E. Trovinger	M. A. Baker	General Electric Co., 1635 Broadway, Fort Wayne, Ind.
Georgia	4	Jan. 14, '04	J. R. Raney	H. P. Peters	Georgia Inst. of Tech., Engg. Experiment Sta., Atlanta 3, Ga.
Houston	7	Aug. 7, '28	E. G. Westheimer	C. R. Wischmeyer	Rice Institute, P. O. Box 1892, Houston 1, Tex.
Illinois Valley	5	June 30, '45	R. P. Pfeiffer	M. V. Meyer	911 So. 17th St., Pekin, Ill.
Iowa	5	June 29, '29	F. E. Keith	A. V. Donnelly	State Univ. of Iowa, 340 Ellis Ave., Iowa City, Iowa
Ithaca	1	Oct. 15, '02	E. M. Guyer	G. E. Dana	N. Y. State Elec. & Gas Corp., Box 1111, Binghamton, N. Y.
Kansas City	7	Apr. 14, '16	H. V. Rathbun	M. L. Perry, Jr.	Black & Veatch, 4706 Broadway, Kansas City 2, Mo.
Lehigh Valley	2	Apr. 16, '21	G. M. Keenan	A. L. Price	Pennsylvania Power & Light Co., Hazleton, Pa.
Los Angeles	8	May 19, '08	J. H. Vivian	E. W. Rockwell	Metropolitan Water District of So. Calif., 306 West 3d St., Los Angeles 13, Calif.
Louisville	4	Oct. 15, '26	H. T. Smith	W. G. Adair	Southern Bell Tel. & Tel. Co., Louisville, Ky.
Lynn	1	Aug. 22, '11	R. E. Franck	T. C. Sargent	Sylvania Elec. Prod., Inc., 60 Boston St., Salem, Mass.
Madison	5	Jan. 8, '09	H. A. Peterson	T. J. Higgins	University of Wisconsin, Madison 6, Wis.
Mansfield	2	Mar. 6, '39	H. R. Delahooke	J. M. Blackhall	North Electric Mfg. Co., Galion, Ohio
Maryland	2	Dec. 16, '04	J. W. Gore	F. Hamburger	Johns Hopkins Univ., Homewood, Baltimore, Md.
Memphis	4	May 22, '30	J. R. Owens	W. J. Fransioli, Jr.	Memphis Light, Gas & Water Div., 179 Madison Ave., Memphis, Tenn.
Mexico	7	June 29, '22	F. Aubert	G. Fortoul	Mexican Light & Power Co., Ltd., Gante No. 20, Mexico D.F., Mexico
Miami	4	Feb. 3, '49	J. Bronaugh	S. G. Kent	W. Killian Drive., P. O. Box 27, Kendall, Fla.
Michigan	5	Jan. 13, '11	O. E. Bowlus	I. B. Baccus	Michigan State College, East Lansing, Mich.
Milwaukee	5	Feb. 11, '10	E. H. Frederick	R. C. Ball	Cutler-Hammer, Inc., 315 No. 12th St., Milwaukee 1, Wis.
Minnesota	5	Apr. 7, '02	A. J. Hendry	G. G. Germain	Westinghouse Electric Corp., Minneapolis, Minn.
Montana	9	June 24, '31	Harry Murphy	C. Beardslee	2124 Roberts, Butte, Mont.
Montreal	10	Apr. 16, '43	A. Malkin	L. K. Hart	Square D Co. of Canada Ltd., 5012 Western Ave., Montreal 28, Que., Canada
Nebraska	6	Jan. 21, '25	C. S. Roadhouse	C. N. Allen	Allis-Chalmers Mfg. Co., 9th & Farnam Sts., Omaha 8, Nebr.
New Mexico-West Texas	7	Mar. 7, '40	J. Armstrong	C. C. Homan, Jr.	El Paso Natural Gas Co., P. O. Box 1492, El Paso, Texas
New Orleans	4	Dec. 8, '33	F. Hollins	H. E. Pritchard, Jr.	5836 General Haig St., New Orleans 19, La.
New York	3	Dec. 10, '19	J. D. Tebo	J. A. Parrott	American Tel. & Tel. Co., 195 Broadway, New York 7, N. Y.
Niagara Frontier	1	Feb. 10, '25	B. S. Rice	C. J. Brumbaugh	129 Hunt Ave., Hamburg, N. Y.
Niagara International	10	Aug. 5, '48	B. A. Bovee	Walter Turecki	The Carborundum Co., Niagara Falls, N. Y.
North Carolina	4	Mar. 21, '29	F. C. De Weese	N. H. Erlandson	Carolina Power & Light Co., Raleigh, N. C.
Northeastern Michigan	5	Feb. 2, '50	F. H. Justin	A. E. Stevens	504 No. Van Buren St., Bay City, Mich.
North Texas	7	May 18, '28	R. L. Biesele, Jr.	E. W. Rogers	Dallas Power & Light Co., Dallas, Tex.
Oak Ridge	4	Feb. 1950	W. J. Pollock	G. A. Holt	105 South Tampa Lane, Oak Ridge, Tenn.
Oklahoma City	7	Feb. 16, '22	R. E. Thornton	J. C. Turner	Southwestern Bell Tel. Co., 1004 Telephone Bldg., Oklahoma City 2, Okla.
Ottawa	10	June 23, '49	W. G. Hoyle	A. M. Pedersen	Hydro-Electric Comm. of Ont., 620 University Ave., Toronto 2, Ont., Canada
Panhandle Plains	7	June 12, '47	G. R. Bunton	D. H. Buck	General Electric Co., 300 So. Polk, Amarillo, Tex.
Philadelphia	2	Feb. 18, '03	S. R. Warren, Jr.	W. K. Denkhaus	Bell Telephone Co. of Pa., 1401 Arch St., Philadelphia, Pa.
Pittsburgh	2	Oct. 13, '02	L. N. Grier	A. A. Johnson	Westinghouse Electric Corp., East Pittsburgh, Pa.
Pittsfield	1	Mar. 25, '04	M. I. Alimansky	E. A. Raney	General Electric Co., 100 Woodlawn Ave., Pittsfield, Mass.
Portland	9	May 18, '09	Howard Arnett	J. D. Frantz	Pacific Pr. & Lt. Co., 920 S. W. 6th Ave., Portland 4, Oreg.
Providence	1	Mar. 12, '20	J. E. Hall	C. B. Leathers	General Electric Co., 111 Westminster St., Providence, R. I.
Richland	9	Apr. 23, '48	F. J. Mollerus	G. M. Clifton	523 North 9th, Pasco, Wash.
Rochester	1	Oct. 9, '14	E. M. Morecock	J. A. Gienger	17 Flower City Park, Rochester 13, N. Y.
Rock River Valley	5	Apr. 23, '47	W. C. Busch	C. F. Vinci	Rockford Machine Tool Co., 2500 Kishwaukee St., Rockford, Ill.
Sacramento	8	June 15, '50	G. A. Fleming	A. B. Johnson	Westinghouse Electric Corp., 1720—14th St., Sacramento 14, Calif.
St. Louis	7	Jan. 14, '03	C. W. Schemm	D. M. Allison	Westinghouse Electric Corp., 411 No. 7th St., St. Louis 1, Mo.
San Diego	8	Jan. 18, '39	J. P. Conner	A. H. Keith	3827 Polk Ave., San Diego 5, Calif.
San Francisco	8	Dec. 23, '04	W. L. Carter	J. C. Beckett	Wesix Electric Heater Co., 390 First St., San Francisco 5, Calif.
Schenectady	1	Jan. 26, '03	D. E. Garr	C. C. Herskind	General Electric Co., Schenectady 5, N. Y.
Seattle	9	Jan. 19, '04	W. S. Gordon, Jr.	L. D. Barter	Westinghouse Electric Corp., 3451 East Marginal Way, Seattle 4, Wash.
Sharon	2	Dec. 11, '25	A. J. Maslin	M. M. Morisuye	84 Buhl Court, Sharon, Pa.
Shreveport	4	June 12, '47	C. M. L. Pons	E. D. Nuttall	Box 1407, Shreveport, La.
South Bend	5	Feb. 26, '41	C. O. Moyer	A. W. Fraps	1260 Longfellow Ave., South Bend 15, Ind.
South Carolina	4	Mar. 2, '40	W. E. Dent	S. A. Ferguson	3608 Wheat St., Columbia 5, S. C.
South Texas	7	May 23, '30	A. C. Alberti	R. A. Nicholson, Jr.	City Public Service Board, Box 1771, San Antonio 6, Tex.
Spokane	9	Feb. 14, '13	S. J. Pope	W. T. Connolly	Washington Water Pr. Co., 825 W. Trent Ave., Spokane 6, Wash.
Springfield	1	June 29, '22	W. L. Vest, Jr.	S. H. Magruder	1387 Main St., Springfield 3, Mass.
Syracuse	1	Aug. 12, '20	H. H. Graley	N. W. Landis	302 Empire Bldg., Syracuse 2, N. Y.
Toledo	2	June 3, '07	D. L. Rexford	W. M. Campbell	2145 Central Grove Ave., Toledo, Ohio
Toronto	10	Sept. 30, '03	J. T. Thwaites	L. S. Lauchland	University of Toronto, Toronto 5, Ont., Canada
Tulsa	7	Oct. 1, '37	G. R. Van Burkleo	V. J. Sittel	Stanolind Pipe Line Co., Box 591, Tulsa 2, Okla.
Urbana	5	Nov. 25, '02	D. F. Hang	J. A. Barkson	1002 West Oregon, Urbana, Ill.
Utah	9	Mar. 9, '17	P. W. Worthen	L. Dale Harris	1738 Logan Ave., Salt Lake City, Utah
Vancouver	9	Aug. 22, '11	F. O. Wollaston	F. Noakes	University of British Columbia, Vancouver, B. C., Canada
Virginia	4	May 19, '22	P. R. Spracher	R. B. Liverman	348—54th St. Newport News, Va.
Washington	2	Apr. 9, '03	F. B. Crider	D. S. Bender	Bell Telephone Labs., Inc., 725—13th St., N. W., Washington 5, D. C.
West Virginia	2	Apr. 9, '40	J. J. FitzGibbon	H. L. Lindsey	Charleston Elec. Supply Co., 914 Kanawha Blvd., Charleston 29, W. Va.
Western Virginia	4	June 23, '49	B. H. Adkins	H. E. Rothwell	2307 Denniston Ave., Roanoke 15, Va.
Wichita	7	Sept. 16, '37	Charles Yoe	O. R. Hantla	Kansas Gas & Electric Co., Box 208, Wichita, Kans.
Worcester	1	Feb. 18, '20	R. E. Pfeif	W. G. Coleman	General Electric Co., 507 Main St., Worcester 8, Mass.
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Charlotte (North Carolina Section)	I. G. Wallace, Jr.	W. C. Burnett	Box 240, Charlotte 1, N. C.
Columbia (South Carolina Section)	Oren Long	J. T. Steppe, Jr.	3950 Live Oak St., Columbia, S. C.
Corpus Christi (South Texas Section)	M. D. Jester	J. E. Dean	Texas College of Arts & Industries, Kingsville, Tex.
Eastern Shore (Maryland Section)	C. D. Appleby	C. M. Mullican, Jr.	Salisbury C & P Telephone Co. of D. C., 208 East Church St., Salisbury, Md.
Fort Worth (North Texas Section)	C. K. Beyette	Harold Farrington	Texas Electric Service Co., P. O. Box 970, Fort Worth 1, Tex.
Fox River Valley (Milwaukee Section)	J. J. Rock	W. W. Lund	Kurz & Root Co., Appleton, Wis.
Freeport (Houston Section)	W. D. Coxe	R. T. Windecker	P. O. Box 33, Lake Jackson, Tex.
Fresno Division (San Francisco Section)	W. M. Green	G. W. Hayden	4325 Iowa Ave., Fresno 2, Calif.
Great Falls (Montana Section)	W. Lowe	J. Radcliffe	2805 First Ave., N., Great Falls, Mont.
Hamilton (Toronto Section)	J. P. Skillen	C. V. Ryder	396 Main St. E., Hamilton, Ont., Canada
Hampton Roads (Virginia Section)	S. H. Fletcher	L. E. Rhinesmith	1119 East Warwick Road, R. D. 1, Box 35, Hilton Village, Va.
Hudson Valley Division (New York Section)	M. F. Clement	A. V. Platter	International Business Machines, Poughkeepsie, N. Y.
Jackson (Miss.) (New Orleans Section)	A. N. Saxon	W. L. Harp	Southern Bell Tel. & Tel. Co., P. O. Box 811, Jackson 106, Miss.
Jacksonville (Florida Section)			
Johnstown (Pittsburgh Section)	B. H. Drum	R. S. Baum	University of Pittsburgh, 325 Cypress Ave., Johnstown, Pa.
Lake Charles (New Orleans Section)	J. J. Alleman	C. Valdez	738 Kirkby St., Lake Charles, La.
Lancaster-York (Maryland Section)	F. C. Sieber	G. E. Conn, Jr.	Allis-Chalmers Mfg. Co., 42 East King St., York, Pa.
Lima (Dayton Section)	O. M. Swain	E. S. Reed	Westinghouse Electric Corp., Lima, Ohio
Mid-State (North Carolina Section)	H. G. Taylor	S. M. Sprowl, Jr.	P. O. Drawer K-1, Greensboro, N. C.
Mobile-Pensacola (Alabama Section)	R. L. Pulley	A. M. Quarterman	Yonge & Hart, 611 Blount Bldg., Pensacola, Fla.
Muscle Shoals (East Tennessee Section)			
Nashville (Memphis Section)	J. L. Simpson, Jr.	W. Criley	Vanderbilt Univ., Nashville 4, Tenn.
New Hampshire (Boston Section)	W. C. Tallman	P. W. Buxton	Public Service Co. of N. H., 205 Main St., Nashua, N. H.
New Jersey Division (New York Section)	F. Seely	E. H. Shrimp	Pub. Serv. Elec. & Gas Co., 938 Clinton Ave., Irvington 11, N. J.
Northwest Arkansas (Arkansas Section)	W. B. Stelzner	F. M. Hinkle	411 Rebecca St., Fayetteville, Ark.
Quad-Cities (Iowa Section)	M. P. Roller	A. W. Kremser	Allis-Chalmers Mfg. Co., 901 Kahl Bldg., Davenport, Iowa
Red River Valley Division (Minnesota Section)	B. H. Barnard	R. Faiman	North Dakota Agri. College, Fargo, N. Dak.
Richmond (Virginia Section)	L. D. Johnson, III	C. E. McMurdo	3523 Patrick Ave., Richmond 22, Va.
Ridgway (Erie Section)	R. F. Edwards	G. F. McGinnis	Box 67, Ridgway, Pa.
St. Lawrence International (Syracuse Section)	P. F. Mengel	G. W. Reed	Clarkson College, Potsdam, N. Y.
St. Maurice Valley (Montreal Section)	D. King	G. Auger	Aluminum Co. of Canada, Shawinigan Falls, P. Q., Canada
San Jose (San Fracisco Section)	W. Raab	A. F. Lowe	Pacific Tel. & Tel. Co., 1199 Lennon Way, San Jose, Calif.
Sangamon (Illinois Valley Section)	C. P. Hafel	F. C. Blythe	P. O. Box 37, Springfield, Ill.
Savannah (Georgia Section)	E. H. Overby	E. B. Dawson	Savannah Armature Works, Inc., 126 West Bay St., Savannah, Ga.
Shasta Division (San Francisco Section)	Roy Greer	A. A. Craig	220 West St., Willows, Calif.
Tacoma (Seattle Section)	H. M. Manning	H. A. Brenner	General Electric Co., P. O. Box 1485, Tacoma, Wash.
Tri-State Division (West Virginia Section)			
West Central Texas Division (North Texas Section)	C. V. Herbert	J. G. McKeown	880 Ross Ave., Abilene, Tex.
West Coast (Florida Section)			
West Michigan (Michigan Section)	P. R. Coffman	L. A. Zahorsky	127 Colfax, N. E., Grand Rapids, Mich.
Wilmington (Philadelphia Section)	W. J. Mearns	M. G. Young	Univ. of Delaware, Newark, Del.
Zanesville (Columbus Section)	A. Wurdack	F. Nikel	743 Convers Ave., Zanesville, Ohio

Geographical District Executive Committees

	District	Chairman (Vice-President, AIEE)	Secretary (District Secretary)	Chairman, District Committee on Student Activities
1	North Eastern	J. G. Tarboux, Cornell University, Ithaca, N. Y.	E. B. Alexander, New York State Elec. & Gas Corp., 62 Henry St., Binghamton, N. Y.	H. F. Cooke, University of Syracuse, Syracuse, N. Y.
2	Middle Eastern	C. G. Veinott, Westinghouse Electric Corp., Lima, Ohio	W. A. Dynes, 312 Lonsdale Ave., Dayton 9, Ohio	J. S. Antel, Jr., George Washington University, Washington 7, D. C.
3	New York City	C. S. Purnell, Westinghouse Electric Corp., 40 Wall St., New York 5, N. Y.	D. W. Taylor, Public Service Elec. & Gas Co., 80 Park Place, Newark 1, N. J.	R. T. Weil, Manhattan College, New York 63. N. Y.
4	Southern	W. J. Seeley, Duke University, Durham, N. C.	Russell Ranson, 116½ East Fourth St., Charlotte 2, N. C.	P. H. Nelson, University of Florida, Gainesville, Fla.
5	Great Lakes	J. R. North, Commonwealth Associates, Inc., 212 W. Michigan Ave., Jackson, Mich.	G. M. Chute, General Electric Co., 700 Antoinette St., Detroit 2, Mich.	H. S. Dixon, North Dakota Agri. College, State College Sta., Fargo, N. Dak.
6	North Central	W. C. DuVall, University of Colorado, Boulder, Colo.	G. E. Gless, Jr., University of Colorado, Boulder, Colo.	E. J. Ballard, Jr., University of Nebraska, Lincoln 8, Nebr.
7	South West	H. R. Fritz, Southwestern Bell Tel. Co., 2502 Telephone Bldg., St. Louis 1, Mo.	R. C. Meyerand, Union Elec. Co. of Missouri, 315 No. 12th Blvd., St. Louis 1, Mo.	A. J. McCrocklin, Jr., University of Texas, Engg. Bldg. 145, Austin 18, Tex.
8	Pacific	R. A. Hopkins, Westinghouse Electric Corp., 600 St. Paul Ave., Los Angeles 14, Calif.	T. M. Blakeslee, Dept. of Water & Power, Box 3669 Terminal Annex, Los Angeles 54, Calif.	R. M. Saunders, University of Calif., Berkeley 4, Calif.
9	North West	J. A. McDonald, General Electric Co., 200 So. Main St., Salt Lake City, Utah	F. O. Wald, Utah Power & Light Co., P. O. Box 899, Salt Lake City 10, Utah	O. C. Haycock, University of Utah, Salt Lake City ,Utah
10	Canada	A. H. Frampton, English Elec. Co. of Canada, Ltd., St. Catharines, Ont., Canada	John I. Gram, Hydro-Electric Power Comm. of Ont., Box 237, Niagara Falls, Ont., Canada	

NOTE: Each District Executive Committee includes also the Chairmen and Secretaries of all Sections within the District, the District Vice-Chairman of the AIEE Membership Committee, and a member of the Sections Committee who is resident in the District.

Student Branches

Name and Location	District	Counselor (Member of Faculty)
*Akron, University of, Akron, Ohio	2	K. F. Sibila
Alabama Polytechnic Institute, Auburn	4	James Chadwick
Alabama, University of, University	4	W. F. Gray
*Alberta, University of, Edmonton, Canada	10	R. E. Phillips
*Arizona, University of, Tucson	8	J. C. Clark
Arkansas, University of, Fayetteville	7	D. D. Lingelbach
British Columbia, University of, Vancouver, Canada	9	W. B. Coulthard
Brooklyn, Polytechnic Institute of, Brooklyn, N. Y., (Day)	3	F. A. Wahlers
Brooklyn, Polytechnic Institute of, Brooklyn, N. Y., (Evening)	3	Anthony B. Giordano
Brown University, Providence, R. I.	1	F. N. Tompkins
*Bucknell University, Lewisburg, Pa.	2	Ralph C. Walker
California Institute of Technology, Pasadena	8	Gilbert D. McCann
*California, University of, Berkeley	8	R. M. Saunders
*Carnegie Institute of Technology, Pittsburgh, Pa.	2	George M. Anderson
Case Institute of Technology, Cleveland, Ohio	2	Carl F. Schuneman
Catholic University of America, Washington, D. C.	2	Joseph C. Michalowicz
Cincinnati, University of, Cincinnati, Ohio	2	A. C. Herweh
Clarkson College of Technology, Potsdam, N. Y.	1	George W. Reed
Clemson A & M College, Clemson, S. C.	4	F. T. Tingley
Colorado A & M College, Fort Collins	6	C. H. Chinburg
*Colorado, University of, Boulder	6	S. I. Pearson
*Columbia University, New York, N. Y.	3	Walter A. LaPierre
*Connecticut, University of, Storrs	1	Clarence W. Schultz
Cooper Union, New York, N. Y.	3	E. W. Starr
*Cornell University, Ithaca, N. Y.	1	W. H. Erickson
Delaware, University of, Newark	2	H. S. Bueche
*Denver, University of, Denver, Colo.	6	A. M. Stiles
*Detroit, University of, Detroit, Mich.	5	H. O. Warner
Drexel Institute of Technology, Philadelphia, Pa.	2	F. C. Powell
Duke University, Durham, N. C.	4	Otto Meier, Jr.
Fenn College, Cleveland, Ohio	2	R. W. Schindler
*Florida, University of, Gainesville	4	Paul H. Nelson
George Washington University, Washington, D. C.	2	J. S. Antel, Jr.
Georgia Institute of Technology, Atlanta, Ga.	4	H. B. Duling
Harvard University, Cambridge, Mass.	1	John C. Fisher
Howard University, Washington, D. C.	2	E. R. Welch
Idaho, University of, Moscow	9	J. H. Johnson
Illinois Institute of Technology, Chicago	5	E. T. B. Gross
*Illinois, University of, Urbana	5	E. A. Reid
*Iowa State College, Ames	5	G. A. Richardson
Iowa, University of, Iowa City	5	E. B. Kurtz
Johns Hopkins University, Baltimore, Md.	2	C. F. Miller
Kansas State College, Manhattan	7	Earl L. Sitz
*Kansas, University of, Lawrence	7	E. B. Phillips
Kentucky, University of, Lexington	4	H. Alex Romanowitz
*Lafayette College, Easton, Pa.	2	J. G. Reifsnyder
Lehigh University, Bethlehem, Pa.	2	W. Lyle Donaldson
Louisiana Polytechnic Institute, Ruston	4	S. P. Gullatt, Jr.
Louisiana State University, Baton Rouge	4	A. K. Ramsey
Louisville, University of, Louisville, Ky.	4	Thomas R. Bailey
*Maine, University of Orono	1	P. M. Seal
Manhattan College, New York, N. Y.	3	Robert T. Weil
*Marquette University, Milwaukee, Wis.	5	E. W. Kane
*Maryland, University of, College Park	2	L. J. Hodgins
*Massachusetts Institute of Technology, Cambridge	1	E. W. Boehne
*Michigan College of Mining and Technology, Houghton	5	G. W. Swenson
Michigan State College, East Lansing	5	M. D. Rogers
*Michigan, University of, Ann Arbor	5	John J. Carey
Milwaukee School of Engineering, Milwaukee, Wis.	5	R. J. Ungrodt
*Minnesota, University of, Minneapolis	5	Paul A. Cartwright
Mississippi State College, State College	4	Paul B. Jacobs, Jr.
*Missouri School of Mines and Metallurgy, Rolla	7	J. W. Rittenhouse
*Missouri, University of, Columbia	7	G. V. Lago
Montana State College, Bozeman	9	R. C. Seibel
*Nebraska, University of, Lincoln	6	E. J. Ballard, Jr.
Nevada, University of, Reno	8	Harold J. Hendriks
*New Hampshire, University of, Durham	1	A. J. Merlini
Newark College of Engineering, Newark, N. J.	3	Robert E. Anderson
*New Mexico College of A & M Arts, State College	7	M. A. Thomas
New Mexico, University of, Albuquerque	7	Ralph W. Tapy
New York, College of the City of, New York	3	Harold Wolf
*New York University, New York	3	B. James Ley
North Carolina State College, Raleigh	4	Arthur R. Eckels
North Dakota Agricultural College, Fargo	5	Harry S. Dixon
*North Dakota, University of, Grand Forks	5	Robert G. Brown
*Northeastern University, Boston, Mass.	1	R. G. Porter
*Northwestern University, Evanston, Ill.	5	A. H. Wing
Norwich University, Northfield, Vt.	1	D. B. Staake
*Notre Dame, University of, Notre Dame, Ind.	5	L. F. Stauder
Ohio Northern University, Ada	2	J. L. Klingenberger
*Ohio State University, Columbus	2	Edmund D. Ayres
*Ohio University, Athens	2	D. B. Green
Oklahoma A & M College, Stillwater	7	David L. Johnson
*Oklahoma, University of, Norman	7	William B. Lewis
*Oregon State College, Corvallis	9	Melvin J. Kofoid
*Pennsylvania State College, State College	2	A. P. Powell
*Pennsylvania, University of, Philadelphia	2	Kenneth A. Fegley
Pittsburgh, University of, Pittsburgh	2	R. C. Gorham
Pratt Institute, Brooklyn, N. Y.	3	R. B. Morgan
*Princeton University, Princeton, N. J.	2	W. H. Surber
Puerto Rico, University of, Mayaguez	3	Garcia de Quevedo
Purdue University, Lafayette, Ind.	5	Stephen Freeman, Jr.
*Rensselaer Polytechnic Institute, Troy, N. Y.	1	E. D. Broadwell
*Rhode Island State College, Kingston	1	Robert S. Haas
Rice Institute, Houston, Texas	7	J. S. Waters
Rose Polytechnic Institute, Terre Haute, Ind.	5	C. C. Knipmeyer
*Rutgers University, New Brunswick, N. J.	3	H. T. Rights
Santa Clara, University of, Santa Clara, Calif.	8	Henry P. Nettesheim
South Carolina, University of, Columbia	4	S. A. Ferguson
South Dakota School of Mines and Technology, Rapid City	6	J. O. Kammerman
South Dakota State College, Brookings	5	John N. Cheadle
*Southern California, University of, Los Angeles	8	Rodney C. Lewis
*Southern Methodist University, Dallas, Texas	7	F. W. Tatum
*Stanford University, Stanford, Calif.	8	Wm. G. Hoover
Stevens Institute of Technology, Hoboken, N. J.	3	W. L. Sullivan
Swarthmore College, Swarthmore, Pa.	2	R. W. Merriam
*Syracuse University, Syracuse, N. Y.	1	Henry F. Cooke
Tennessee, University of, Knoxville	4	W. O. Leffell
*Texas, A & M College of, College Station	7	N. F. Rode
*Texas Technological College, Lubbock	7	V. D. Wade
*Texas, University of, Austin, and Texas Western College Sub-Branch, El Paso	7	A. J. McCrocklin, Jr.
Toronto, University of, Toronto, Ont., Canada	10	L. S. Lauchland
*Tufts College, Medford, Mass.	1	G. H. Hammond
*Tulane University, New Orleans, La.	4	Daniel H. Vliet
Union College, Schenectady, N. Y.	1	Owen G. Owens
*Utah, University of, Salt Lake City	9	O. C. Haycock
Vanderbilt University, Nashville, Tenn.	4	Walter Criley
Vermont, University of, Burlington	1	Howard M. Smith, Jr.
Villanova College, Villanova, Pa.	2	J. B. Clothier
Virginia Military Institute, Lexington	4	J. S. Jamison
Virginia Polytechnic Institute, Blacksburg	4	Claudius Lee
Virginia, University of, Charlottesville	4	Gordon K. Carter
Washington, State College of, Pullman	9	O. E. Osburn
*Washington, University of, Seattle	9	H. M. Rustebakke
Washington University, St. Louis, Mo.	7	Pierre M. Honnell
*Wayne University, Detroit, Mich.	5	Edward L. Fairchild
West Virginia University, Morgantown	2	Everette C. Dubbe
Wisconsin, University of, Madison	5	John Baird
*Worcester Polytechnic Institute, Worcester, Mass.	1	Donald C. Alexander
*Wyoming, University of, Laramie	6	R. K. Beach
*Yale University, New Haven, Conn.	1	R. R. Shank

Total Branches 130

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* Joint AIEE-IRE Branches.

INSTITUTE ACTIVITIES

Tentative Technical Program Released for Middle Eastern District Meeting

The 1950 AIEE Middle Eastern District Meeting will be held in Baltimore, Md., October 3–5, with headquarters in the Lord Baltimore Hotel. In addition to the comprehensive technical program, a stag smoker, cabaret dance, inspection trips, and a special ladies' program have been arranged by the committee.

This District meeting also has been selected by the AIEE Air Transportation Committee for its annual national meeting and committee members from all parts of the United States are expected to attend. The selection is believed appropriate because of the Glenn L. Martin plant located in Baltimore and the recent dedication of the new Friendship International Airport at which special inspection trips have been arranged. All AIEE members and guests may attend.

The meeting will be opened on Tuesday, October 3, with the general session at which the subject, "Developing Engineers for Industry," will be discussed by Dr. W. B. Kouwenhoven, Dean, School of Engineering, The Johns Hopkins University; Everett S. Lee, General Electric Company; and Titus G. LeClair, President, AIEE.

ENTERTAINMENT

An entertainment feature of the meeting will be a stag smoker in the Calvert Room of the Lord Baltimore Hotel on Tuesday evening at 6:00 p.m. It will consist of an old-time Maryland oyster roast with all of its elaborate trimmings, in addition to various other types of food. Rivers Chambers and his orchestra will furnish music, and boxing matches will be held during the evening. Tickets are priced at $6 per person (with a special $3 rate for Student members); these prices include tax and gratuity.

On Wednesday evening at 6:00 p.m., a cabaret dance will be held. Dress is to be informal and there will be door prizes and music by Jack Lederer's orchestra. No admission fee will be charged.

For the convenience of ladies at the meeting, a suite of rooms will be open at all times to provide for their comfort and to serve as a meeting place. In addition, the following program has been arranged.

From 2:00 to 5:00 p.m. on Monday, hostesses will be present in the Hostess Room to entertain and welcome guests. On Tuesday morning, shopping tours or visits to points of interest may be arranged, and at 2:00 p.m. the ladies will take a tour through McCormick and Company House of Spices, the world's largest spice processor; tea will be served in the Tea House. At 6:00 p.m., predinner refreshments will be served in the Hostess Rooms, followed by dinner in the Caswell Room, including a fashion show by Hutzler Brothers, cards and games, and music; dress optional, $4 (all-inclusive). On Wednesday, October 4, at 9:00 a.m., a trip will be taken to Annapolis by bus, consisting of visits to various historical houses, luncheon at Carvel Hall, a tour of the Naval Academy, and a reception at the Governor's Mansion; fee is $4, all-inclusive.

For AIEE members wishing to golf, arrangements have been made at the Rolling Road Golf Club in Catonsville, while those wishing to bowl may do so at the Recreation Bowling Alleys. Other sports events of importance will be posted on the bulletin board. All reservations for these events will be made at the reservation desk.

INSPECTION TRIPS

Highlighting the Middle Eastern District Meeting will be inspection trips to several of Baltimore's large nationally known industrial plants and other interesting locations. It will assist the committee materially if those expecting to take the trips will indicate their choice on the advance registration card. Otherwise, arrangements should be made immediately upon registration at meeting headquarters. (It will be necessary for those visiting Aberdeen Proving Ground and the Glenn L. Martin plant to have proof of citizenship with them. Birth certificates, passports, company identification cards, and so forth, will constitute such proof. Automobile drivers licenses and similar identification will not.) Following is a schedule of the trips:

Bendix Radio Division of Bendix Aviation Corporation (Tuesday afternoon, October 3). This thoroughly modern plant is engaged largely in the manufacture of radio and television sets for residences, radio and electronic control for the armed services, ground-approach landing equipment for air fields, and other electronic equipment. The mass production methods and well-planned factory layout should make this an interesting plant to visit.

Locke Inc. (Tuesday afternoon, October 3). The world's largest manufacturer of wet process insulators used in electrical transmission; the company was founded in 1893 by Fred M. Locke, inventor of the wet process insulator. Now an affiliate of the

Among the inspection trips scheduled for the AIEE Middle Eastern District Meeting to be held in Baltimore, Md., in October, are the Bendix radio plant where (left) a communications radio assembly line is viewed in operation, and the Ballistic Research Laboratory at Aberdeen Proving Ground (right). In this general view of the Fixed Throat Wind Tunnel a test of a guided missile is seen in progress. The pressures acting on the model are recorded by the manometers in the background. The dials in the right foreground measure the lift, drag, and pitching moment data from which right missile stability and performance can be calculated

Tentative Technical Program

Middle Eastern District Meeting, Baltimore, October 3-5

Tuesday, October 3

10:00 a.m. General Session

Thomas W. Trice, presiding

Opening Remarks. J. W. Gore, Chairman, AIEE Maryland Section

Developing Engineers for Industry

Mutual Obligations—the University, the Engineer, Industry, the Engineering Society. *Dr. W. B. Kouwenhoven*, The Johns Hopkins University

Industry Appraises and Develops the Engineer. *Everett S. Lee*, General Electric Company

Is the College Graduate Educated? *Titus G. LeClair*, President, AIEE

Awards Presentation. District 2 Papers. C. G. Veinott, Vice-President, District 2

2:00 p.m. Computing Devices

K. A. Pullen, Jr., presiding

DP. The EDVAC—Basic Principles.** *S. E. Gluck*, University of Pennsylvania

DP. The Installation and Modification of the EDVAC.** *R. L. Snyder, Jr.*, Aberdeen Proving Grounds

DP. Adders and Counters.** *H. J. Gray*, University of Pennsylvania

DP. Systematization of Tube Surveillance in Large-Scale Computers.** *Homer Spence*, Aberdeen Proving Grounds

DP. Stability Diagrams for Feedback Systems.** *J. F. Koenig*, University of Illinois

2:00 p.m. Relays

W. G. Withington, presiding

50-189. Theory and Application of Transformer Differential Protection. *G. W. McKenna*, Philadelphia Electric Company

50-190. Differential Relay Sensitivity Adjuster. *C. L. Headley*, Consolidated Gas Electric Light and Power Company of Baltimore

DP. Improved Bus Protection.** *L. E. Goff*, General Electric Company

DP. Symmetrical Components as Applied to Protective Relaying.** *W. K. Sonnemann*, Westinghouse Electric Corporation

2:00 p.m. Rotating Machinery I—D-C

B. H. Caldwell, presiding

50-191. Resistance Commutation. *F. D. Olney*, General Electric Company

50-192. Current in Equalizer Connections of D-C Machine Armature Windings. *T. M. Linville, D. P. Strang*, General Electric Company

50-193. Measurement and Calculation of D-C Machine Armature Circuit Inductance. *H. D. Snively, Paul B. Robinson*, General Electric Company

50-194. Measurement of Insulation Resistance on Energized Systems. *E. L. Brancato, A. T. McClinton*, Naval Research Laboratory

2:00 p.m. Air Transportation I

W. V. Boughton, presiding

50-195. 5-Kva 400-Cycle Aircraft Inverter With Amplistat Regulator. *R. E. Morgan, J. A. Walley*, General Electric Company

DP. Aircraft Electric Motors Need Test Equipment.** *I. E. Ross*, General Electric Company

DP. An Electronic Speed Control for Aircraft Inverters.** *A. W. Forsberg, Herbert Gumaer*, Gaveco Laboratories, Inc.

DP. Stopping Devices for 400-Cycle Motors.** *L. A. Zahorsky*, Lear, Inc.

50-196. Tracking Radio Noise on Aircraft. *T. B. Owen*, Hughes Aircraft Company

DP. Comparison of Electric, Hydraulic, and Pneumatic Actuators for Aircraft.** *H. M. Geyer, R. C. Treseder*, General Motors Corporation

Wednesday, October 4

9:30 a.m. Electronic Devices I

C. V. O. Terwilliger, presiding

DP. Instrumentation on Transistors.** *C. B. Brown*, Naval Ordnance Laboratory

DP. A Submicrosecond Timer.** *R. H. F. Stresau*, Naval Ordnance Laboratory

DP. Underwater Telemetering.** *J. M. Norton* Naval Ordnance Laboratory

DP. X-Ray Gauge for Steel Mill Service.** *Z. L. Collins*, Westinghouse Electric Corporation

9:30 a.m. Electric Phenomena and the Human Body

W. B. Kouwenhoven, presiding

DP. Significance of the Electric Resistance of the Skin in Medicine.** *C. P. Richter*, The Johns Hopkins Hospital

DP. Electric Observations on the Conscious Brain.** *Curtis Marshall*, The Johns Hopkins Hospital

DP. The Use of Stable Isotopes in Medical Research.** *Theodore Enns*, The Johns Hopkins Hospital

DP. Use of Counter Shock in Recovery of the Fibrillating Heart.** *W. B. Kouwenhoven*, The Johns Hopkins University; *Alfred Blalock*, The Johns Hopkins Hospital

9:30 a.m. Industrial Control

F. O. Schnure, presiding

DP. A New Shoe Brake With Two Magnets.** *T. W. Driesch*, General Electric Company

50-197. The Operating Speed of D-C Magnet Brakes. *J. E. Ryan, T. M. Spitler*, General Electric Company

—PAMPHLET reproductions of authors' manuscripts of the numbered papers listed in the program may be obtained as noted in the following paragraphs.

—PRICES for papers, irrespective of length, are 30 cents to members (60 cents to nonmembers) whether ordered by mail or purchased at the meeting. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

—COUPON books in nine-dollar denominations are available for those who may wish this convenient form of remittance.

—THE PAPERS regularly approved by the Technical Program Committee ultimately will be published in Proceedings and Transactions; also, each is scheduled to be published in Electrical Engineering in digest or other form.

DP. Modernization of Sheet and Strip Copper Facilities at Revere Copper and Brass, Inc.** *W. T. Bertier*, Revere Copper and Brass, Inc.; *E. E. Vonada*, The Reliance Electric and Engineering Company

DP. Primary Power Requirements for X-Ray Apparatus.** *W. S. Lusby*, Westinghouse Electric Corporation

9:30 a.m. Rotating Machinery II—A-C

W. G. Withington, presiding

50-198. A-C Series Motors—A Design Method. *S. S. L. Chang, J. H. Karr*, Robbins and Myers, Inc.

50-199. Investigation and Elimination of Unusual Vibration in the Field on a Large Single-Phase Frequency Changer. *W. M. H. Ballantyne* (Deceased), *J. E. Allen*, Safe Harbor Water Power Corporation; *R. A. Baudry*, Westinghouse Electric Corporation

50-200–ACO.* An Analysis of Rotating Machines *R. L. Cosgriff, E. H. Gamble*, Curtiss-Wright Corporation

DP. Thermalastic Insulation for Turbine Generators.** *C. M. Laffoon, G. L. Moses*, Westinghouse Electric Corporation

50-201. Design Calculations for A-C Generators. *David Ginsberg*, Engineer Research and Development Laboratories. Presentation by title only

9:30 a.m. Air Transportation—II

D. E. Fritz, presiding

DP. Circuit Interrupting Phenomena at Altitude** *J. P. Dallas*, Hughes Aircraft Company

50-202. Aircraft Circuit Breakers for 28 and 120 Volts D-C. *B. S. Beall, III, P. J. Reifschneider*, General Electric Company. Presentation by title only

DP. Aircraft Cutouts and Contactors for Interrupting High Direct Voltages.** *R. L. Harrison*, Hartman Electrical Manufacturing Company

50-203. An Environment-Free 120-Volt D-C High Performance Limit Switch. *T. R. Stuelpnagel*, Hughes Aircraft Company

50-204. The Design of Reactors for Radio Interference Filters. *L. I. Knudson*, General Laboratory Associates, Inc.

2:00 p.m. Electronic Devices II

C. V. O. Terwilliger, presiding

DP. Wind Tunnel Instrumentation at the Naval Ordnance Laboratory.** *L. P. Gieseler*, Naval Ordnance Laboratory

DP. Electric Equipment and Control System of the White Oak Supersonic Wind Tunnels.** *B. D. Gilbert*, Naval Ordnance Laboratory

DP. Instrumentation Techniques Used With Naval Ordnance Laboratory Air Guns.** *G. Stathopoulos*, Naval Ordnance Laboratory

DP. Precision Magnetic Tape Recordings of Low-Frequency Signals.** *S. J. Raff*, Naval Ordnance Laboratory

2:00 p.m. Electric Welding

T. B. Jones, presiding

DP. Radio Interference Aspects of High-Frequency Stabilized Welding Transformers.** *R. G. Klause*, United States Naval Engineering Experiment Station

DP. Instrumentation for Investigating the Quality of Electric Welds.** *Fritz Albrecht*, Glenn L. Martin Company

DP. Effect of Cover Characteristics on Electrical Behavior of Electrodes.** *E. B. Lutes*, Arcrods Corporation

DP. Automatic All-Position Welding Head for Electrode Testing.** *Bella Ronay*, United States Naval Engineering Experiment Station

DP. D-C Arcs With High-Speed Electrodes.** *W. B. Kouwenhoven, T. B. Jones*, The Johns Hopkins University

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* **ACO:** Advance copies only available; not intended for publication in *Transactions*.

** **DP:** District paper; no advance copies are available; not intended for publication in *Transactions*.

2:00 p.m. Magnetics

C. H. Rothauge, presiding

50-205. Series-Connected Saturable Reactor With Comparatively High Control Source Impedance. *H. F. Storm*, General Electric Company

50-206. Determination of Steady-State Performance of Self-Saturating Magnetic Amplifiers. *Edward J. Smith*, Polytechnic Institute of Brooklyn

50-207 ACO. Magnetic Amplifier Application Problems. *F. S. Malick*, Westinghouse Electric Corporation

DP.** **The Mechanical Rectifier.** *Otto Jensen*, ITE Circuit Breaker Company

2:00 p.m. Land Transportation

C. W. Miller, presiding

DP.** **Motors and Control for Diesel Electric Locomotives.** *T. L. Weybrew*, Westinghouse Electric Corporation

DP.** **Electric Drives for Baltimore's New Ore Handling Facilities.** *C. B. Risler*, Westinghouse Electric Corporation

DP.** **Radio Communications in the Railroad Industry.** *L. J. Prendergast*, Baltimore and Ohio Railroad

DP.** **Sealed Ignitron Rectifiers for Urban Transit Power Supply.** *T. F. Perkinson*, General Electric Company

2:00 p.m. Electric Substations

S. A. Rittenhouse, presiding

DP.** **Switching High-Voltage Shunt Capacitor Banks.** *A. W. Funkhouser*, Indianapolis Power and Light Company; *R. C. Van Sickle, D. F. Shankle*, Westinghouse Electric Corporation

DP.** **Group Regulation of Urban 4-Kv Feeders.** *H. B. Peck, C. L. Grim*, Consolidated Gas Electric Light and Power Company of Baltimore

DP.** **Bus and Individual Feeder Regulation.** *E. M. Hunter, D. R. Samson*, General Electric Company

DP.** **Power for the Small Factory.** *L. W. Moxey, III*, Keller-Pike Company

DP.** **High-Voltage Circuit Interruption.** *S. C. Killian*, Delta Star Electric Company

Thursday, October 5

9:30 a.m. Transmission and Distribution I

W. J. Witte, presiding

50-163. A Method of Estimating Lightning Performance of Transmission Lines. *Lightning and Insulator Subcommittee*

DP.** **Operating and Economic Benefits Realized From Application of 3-Phase Grounded Neutral System in Baltimore.** *H. C. Louis*, Consolidated Gas Electric Light and Power Company of Baltimore, Md.

DP.** **60-Kv Medium-Pressure Gas-Filled Cable and Conduit Installation.** *G. C. McCabe*, Potomac Electric Power Company

DP.** **Increasing the Load Rating of a 110-Kv Overhead Transmission Line.** *J. E. Hipp, E. F. Wolf*, Consolidated Gas Electric Light and Power Company of Baltimore

9:30 a.m. Insulation

R. L. McCoy, presiding

DP.* **Silicone Fluid Surface Treatment for Insulators Operating in Contaminated Atmospheres.** *A. L. Baldock*, General Electric Company; *R. H. Lee*, E. I. du Pont de Nemours and Company; *H. A. Frey*, Locke, Inc.

DP.** **Live-Line Insulator Washing With a Low Pressure Water Stream.** *I. F. Freed*, Consolidated Gas Electric Light and Power Company of Baltimore

DP.** **Basic Impulse Insulation Levels and Their Relation to Outdoor Switch and Bus Insulators.** *R. L. McCoy*, Locke, Inc.

9:30 a.m. Air Transportation—III

S. D. Summers, presiding

DP.** **Effect of Short Circuits on Distribution System Design for 28-Volt D-C Aircraft Power Systems.** *E. S. Sherrad, K. E. Carlson*, General Electric Company

50-213. Dynamic Characteristics of Carbon-Pile Voltage Regulators. *R. L. Mills*, Magnolia Oil Corporation. (Formerly with Naval Research Laboratory)

50-208. Transient Analysis of a Voltage-Regulated Aircraft D-C System. *D. G. Scorgie*, Naval Research Laboratory

DP.** **Aircraft Electric System Integrity Increased by an Insulated Isolated Bus.** *H. O. Davis, L. D. MacDonald*, Lockheed Aircraft Corporation

DP.** **Wide-Speed-Range A-C Electric Systems for Aircraft Use.** *H. B. James, R. P. Judkins, C. L. Mershon*, Westinghouse Electric Corporation

9:30 a.m. Television—I

S. C. Miller, presiding

DP.** **Ultrahigh-Frequency Television Design.** *F. R. Norton*, Bendix Aviation Corporation

DP.** **Blocking Tube Oscillator Design Considerations in the Television Receiver.** *A. Giordano*, Allen B. DuMont Laboratories, Inc.

DP.** **Synchronous Circuit Design for Good Noise Immunity.** *N. S. Kornetz*, Westinghouse Electric Corporation

DP.** **Influence of Power System Voltage on Television Receivers.** *H. E. Campbell*, General Electric Company

2:00 p.m. Transmission and Distribution II

W. J. Witte, presiding

DP.** **Line Noise and Attenuation as Factors in Power Line Carrier Applications.** *J. A. Becker, J. C. G. Carter*, Westinghouse Electric Corporation

DP.** **Should Residential Service Drops Be Three Wire?** *R. D. Bader, B. C. H. Meyers*, Consolidated Gas Electric Light and Power Company of Baltimore

DP.** **Chemical Brush Control on Rural Power Systems.** *C. J. Waldron*, Rural Electrification Administration

DP.** **Low-Voltage Capacitor Applications on Secondary Networks.** *V. A. Rydbeck*, General Electric Company

2:00 p.m. Instruments and Measurements

W. R. Hedeman, Jr., presiding

DP.** **Instrumentation for Aircraft Navigation.** *W. L. Webb*, Bendix Aviation Corporation

DP.** **Meteorology and Electronics.** *Howard Orville*, Bendix Aviation Corporation

50-214 ACO. An Ultrasonic Method for Measuring Water Velocity. *W. B. Hess*, Safe Harbor Water Power Corporation; *R. C. Swengel*, Consultant; *S. K. Waldorf*, Pennsylvania Water and Power Company

50-209. Electrical Instrumentation in Medical Research. *J. M. Benjamin, Jr.*, Franklin X-Ray Company; *John Hale, E. L. Carstensen, H. E. Tompkins*, University of Pennsylvania

2:00 p.m. Air Transportation—IV

J. D. Miner, presiding

DP.** **Electric Drives for Large Wind Tunnels.** *H. B. Bunce, R. J. Lusk*, Westinghouse Electric Corporation

50-210. Automatic Feathering—To Reduce the Hazard of Aircraft Engine Failure at Take-off. *W. L. Kershaw*, The Glenn L. Martin Company

50-211. Aluminum Conductors From the Aircraft Manufacturer's Viewpoint. *W. W. Schumacher*, The Glenn L. Martin Company

DP.** **Controlled Power for Starting Jet Engines.** *E. A. Fuchs*, General Electric Company

50-212. Analogue Techniques for Turbojet Thrust Instrumentation. *E. S. Van Valkenburg, N. W. Matthews*, Naval Research Laboratory

2:00 p.m. Television—II

S. C. Miller, presiding

DP.** **A Building-Block-Type Television Transmitter.** *Paul Breen*, Allen B. DuMont Laboratories, Inc.

DP.** **Network Television Transmission.** *J. A. Parrott*, American Telephone and Telegraph Company

DP.** **Leased Short-Haul Television Channels in Maryland.** *W. W. Holloway*, The Chesapeake and Potomac Telephone Company of Baltimore City

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General Electric Company, Locke has complete facilities for the development, manufacture, and testing of standard and special insulators of all kinds, as well as line hardware. During a trip through the plant, one will see new semi-automatic machines for forming suspension and switch insulators, modern forging presses for making line hardware, and the recently mechanized assembly line for suspension and switch-type insulators.

Riverside Generating Station (Tuesday afternoon, October 3). This most modern electric generating plant of the Consolidated Gas Electric Light and Power Company of Baltimore was placed in operation in December 1942. Its present capacity of 180,000 kw consisting of three 60,000-kw hydrogen-cooled turbine generators which operate at 3,600 rpm, with throttle conditions of 850 pounds per square inch gauge and 900 degrees Fahrenheit. Each unit is supplied by its own boiler and each of the three boilers has a rated capacity of 550,000 pounds of steam per hour. At present a fourth unit is being installed, scheduled for operation in August 1951. It will have a rating of 75,000 kw with steam conditions at the throttle of 1,450 pounds per square inch gauge and 1,050 degrees Fahrenheit. Its boiler will have a rated capacity of 625,000 pounds of steam per hour.

A luncheon will be held at the plant prior to the inspection.

Aberdeen Proving Ground—Ballistic Research Laboratories and Wind Tunnel (Wednesday afternoon, October 4). Aberdeen Proving Ground, located on Chesapeake Bay about 30 miles from Baltimore, is the hub of Ordnance activities for the research, development, and testing of arms, ammunition, combat vehicles, and so forth, for the Armed Forces. Of particular interest to members of the AIEE are the Ballistics Research Laboratories and Wind Tunnel. The laboratories contain several computing machines: International Business Machines relay calculators, a Bell relay computer, ENIAC, EDVAC, and ORDVAC. These devices are used to solve computation problems arising in Ordnance and other government agencies, with particular reference to the theory of projectile motion, trajectories, and so on. The Wind Tunnel, or "Bomb Tunnel" as it is called, is equipped with five centrifugal compressors with a combined horsepower of 13,000 and is used for testing models of guided missiles and supersonic aircraft, models of bombs and projectiles, air flow around and forces acting upon aerodynamic objects, and so forth.

It will be necessary for those taking this trip to have proof of citizenship with them.

Glenn L. Martin Company (Wednesday afternoon, October 4). This aircraft manufacturing plant is located at Middle River, about ten miles east of Baltimore. The plant has a floor area of 2,700,000 square feet, covers 958 acres, and includes four huge production buildings with latest machinery and equipment, buildings for engineering, personnel, and administrative employees, as well as a modern completely equipped airport. Present employment is approximately 9,000.

The plant is engaged in the development, design, manufacture, and testing of many types of aircraft, including jet-propelled airplanes for private air lines.

It will be necessary for those taking this trip to have proof of citizenship with them. Attendance on the trip will be limited to 100, with first choice going to those who sign for it on the advance registration card.

Westinghouse Electric Corporation, Electronics Division (Wednesday afternoon, October 4). This plant was built during the war when Westinghouse was engaged in the manufacture of radar and other electronic equipment for the Armed Forces. At the present time, manufacturing operations include microwave equipment, high-frequency heating equipment, radar, broadcast transmitters, power-line carrier equipment, and industrial radios.

Friendship International Airport (Thursday morning, October 5). This airport, dedicated by President Truman on June 24, 1950, was built at a cost of $15,000,000, and is five times the size of the National Airport in Washington and four times larger than New York's LaGuardia Field. The site covers 3,200 acres on a man-built plateau 140 feet above sea level, the highest airport elevation on the Atlantic seaboard. The instrument landing runway stretches 9,450 feet and is 200 feet wide. It will accomodate any type of aircraft now flying.

Luncheon will be provided at the airport.

HOTEL ACCOMMODATIONS

Hotel reservations will be available at the Lord Baltimore Hotel, Baltimore and Hanover Streets. Applications for accommodations should be forwarded promptly to the Lord Baltimore, and confirmation will be made directly by the hotel. Hotel rates are

Single room (for one): $4, $4.25, $4.50, $4.75, $5, $5.25, $6, $6.50, $7.50, $8
Twin bedroom (for two): $7.50, $8, $8.50, $9, $10, $10.50
Double room (for two): $6.50, $7, $7.50, $8.50, $9, $10, $10.50
Suite (parlor, bedroom, and two baths for one or two): $18
Three in a room, $2 additional charge for third occupant

ADVANCE REGISTRATION

Advance registration cards should be filled out as soon as possible and forwarded to Eduard Fritz, Chairman, Registration Committee, AIEE Middle Eastern District Meeting, care of Pennsylvania Water and Power Company, Post Office Box 2076, Baltimore 3, Md. Member reservation fee is $2; nonmember's fee is $3; enrolled students and members of families, no fee.

DISTRICT MEETING COMMITTEE

Members of the District Meeting Committee are as follows: Thomas E. Marburger, General Chairman; G. Russell Page, Arrangements; L. G. Smith, Students; Paul L. Betz, Technical Meetings; Thomas W. Trice, Special Meetings; M. C. Albrittain, Finance; T. H. Marshall, Jr., Publicity; Donald Gunn, Smoker; W. C. Wilkenson, Sports; Charles Wallace, Entertainment; C. R. Durling, Cabaret Dance; Eduard Fritz, Registration; C. S. Fiske, Inspection Trips; Mrs. J. Lawrence Hildebrandt, Ladies.

Host for the meeting is the AIEE Maryland Section of which John W. Gore is Chairman, John McGee is Vice-Chairman, and Ferdinand Hamburger is Secretary.

Future AIEE Meetings

Middle Eastern District Meeting
Lord Baltimore Hotel, Baltimore, Md.
October 3–5, 1950
(*Final date for submitting papers—closed*)

AIEE/IRE Conference on Electronic Instrumentation in Nucleonics and Medicine
Park-Sheraton Hotel, New York, N. Y.
October 23–25, 1950

Fall General Meeting
Skirvin Hotel, Oklahoma City, Okla.
October 23–27, 1950
(*Final date for submitting papers—closed*)

Conference on Electrical Engineering in the Machine Tool Industry
Worcester, Mass.
November 15–17, 1950 (rescheduled from October 11–13)

Conference on High-Frequency Measurements
Hotel Statler, Washington, D. C.
January 10–12, 1951

Winter General Meeting
Hotel Statler, New York, N. Y.
January 22–26, 1951
(*Final date for submitting papers—October 24*)

Southern District Meeting
Miami, Fla.
April 11–13, 1951
(*Final date for submitting papers—January 11*)

North Eastern District Meeting
Syracuse, N. Y.
May 2–4, 1951
(*Final date for submitting papers—February 1*)

Great Lakes District Meeting
Madison, Wis.
May 17–19, 1951
(*Final date for submitting papers—February 16*)

Summer General Meeting
Royal York Hotel, Toronto, Ontario, Canada
June 25–29, 1951
(*Final date for submitting papers—March 27*)

Pacific General Meeting
Portland, Oreg.
August 20–23, 1951
(*Final date for submitting papers—May 21*)

AIEE Board of Directors Holds Regular Meeting in Pasadena

A regular meeting of the AIEE Board of Directors was held in the Huntington Hotel, Pasadena, Calif., June 15, 1950, during the recent Summer and Pacific General Meeting.

The following resolution in memory of Past President Charles E. Skinner, who died on May 12, was adopted:

Resolved: That, upon behalf of the membership of the American Institute of Electrical Engineers, the Board of Directors hereby expresses keenest regret at the death of Doctor Charles Edward Skinner, President of the Institute, 1931–32, and Honorary Member, 1945, and extends deepest sympathy to members of his family.

Recommendations adopted by the Board of Examiners on May 18, 1950, were approved. Upon recommendation of the Board of Examiners, the following actions were taken: 3 applicants were transferred to the grade of Fellow; 44 applicants were transferred to the grade of Member; 35 applicants were elected to the grade of Member; 2 applicants were re-elected to the grade of Member; 812 applicants were elected to the grade of Associate; 8 applicants were re-elected to the grade of Associate; 1 applicant was reinstated in the grade of Associate; 581 student members were enrolled.

Expenditures of $69,520.76 in June were reported by the Finance Committee, and approved by the Board of Directors. The income for the period October 1–May 31 was reported as $495,464, as compared with $480,104 for the same period last year.

The annual Report of the Board of Directors for the fiscal year ended April 30, 1950, was approved.

H. H. Henline was reappointed Secretary of the Institute for the administrative year beginning August 1, 1950.

The regular traveling expense allowance was authorized for a joint conference on Student activities of Districts 8 and 9 and the University of British Columbia Branch, in Pasadena, during the Summer and Pacific General Meeting.

Upon recommendation of the Sections Committee, the Board of Directors authorized the establishment of a Sacramento Section, with a territory composed of the California Counties: Colusa, Eldorado, Nevada, Placer, Sacramento, Sutter, Yolo, and Yuba; and approved the following changes in Section territories:

Park County, Wyo., transferred from the Utah Section to the Montana Section.

Putnam County, Ohio, transferred from the Toledo Section to the Dayton Section.

Logan County, Ohio, transferred from the Columbus Section to the Dayton Section.

Upon recommendation of the Standards Committee, the establishment of a joint AIEE-Institute of Radio Engineers Committee on Noise Definitions was authorized. Its scope is defined as follows:

The scope of this committee shall be to prepare an explanatory statement of the different types of noise and interference encountered in communication engineering and associated fields; to prepare a list of terms pertaining to noise and signal-to-noise ratio; and to formulate definitions for those terms; the findings of this committee to be transmitted to other existing committees.

The following dates for meetings previously authorized were recommended by the Committee on Planning and Co-ordination and approved by the Board of Directors: Great Lakes District Meeting, Madison, Wis., May 17–19, 1951; Pacific General Meeting, Portland, Oreg., August 20–23, 1951; Pacific General Meeting, Phoenix, Ariz., August 19–22, 1952.

In view of the decision of the Board of Directors, in April, to eliminate all ex-officio committee memberships provided for in the Bylaws, and the resulting problems, the Technical Program Committee had voted to recommend the calling of "a conference of the technical committee chairman and such other chairmen as may be considered desirable at such general meetings as deemed necessary and with the President of the Institute as presiding officer for the purpose of providing a forum for the expression of ideas and suggestions." This plan was approved by the Board of Directors.

A recommendation of the Committee on Student Branches that the Student dues be increased to $5 per year, with the understanding that additional services will be rendered to the Branches, was approved in principle, to take effect May 1, 1951.

Upon recommendation of the Committee on Constitution and Bylaws, the following three paragraphs were added between the second and third existing paragraphs of Section 1 of the Bylaws:

> A member of the Institute may use his membership designation for purely personal purposes only. When used, the designation shall include his membership grade.
>
> A corporation, association, firm, or other organization may not itself use membership designations because of membership in the Institute of its representatives or members of its staff.
>
> Personal use of Institute symbols by a member shall be limited to the appropriate officially issued badge to which he is entitled. Institute symbols, such as imprints of the badge design, may be used only in connection with Institute business.

Also, upon recommendation of that committee, Section 76 of the Bylaws was amended to read as follows:

> The Committee on Award of Institute Prizes shall consist of five members-at-large appointed by the President, one of whom shall be the chairman, and two members appointed from each Technical Division.

The Committee on Constitution and Bylaws was requested to make a general study of the Constitution and Bylaws and to recommend desirable amendments.

Walter J. Barrett was elected to represent the Board of Directors upon the Board of Trustees of the AIEE Retirement System to succeed Mr. Yerkes, whose term on the Board of Directors expires July 31.

James F. Fairman was appointed AIEE representative on the Exploratory Group on Unity in the Engineering Profession, succeeding T. G. LeClair, who wished to be relieved of that assignment because of his added duties as President.

The Board of Directors authorized the Technical Advisory Committee to approve, in the name of the Institute, definitions of activities and definitions of fields of specialization in electrical engineering, under preparation for the Department of Defense by a committee of the Engineers Joint Council.

The Conference of Vice-Presidents and District Secretaries had voted to recommend the elimination of the District Co-ordinating Committee, provided for in Section 32 of the Bylaws. This was approved in principle.

After a discussion of the advisability of restricting appointment to Institute committees to AIEE members, the following action was taken:

> *Voted* that it is the sense of the Board of Directors that no person who is not a member of the Institute should be appointed to any committee of the Institute without specific approval of the Board of Directors.

A report on the recent Membership Opinion Poll and the action of the Board of Directors resulting from it appeared in the August issue of Electrical Engineering.

Various other matters were discussed.

Present at the meeting were

President J. F. Fairman; Past President B. D. Hull; Vice-Presidents J. L. Callahan, W. C. DuVall, A. H. Frampton, R. A. Hopkins, Richard McKay, G. N. Pingree, E. W. Seeger, W. J. Seeley, Victor Siegfried, C. G. Veinott; Directors W. J. Barrett, E. W. Davis, W. L. Everitt, C. W. Fick, R. T. Henry, N. B. Hinson, M. D. Hooven, F. O. McMillan, Elgin B. Robertson, H. J. Scholz, E. P. Yerkes; Secretary H. H. Henline; and by invitation: incoming President T. G. LeClair; Past President R. W. Sorensen (Part Time); incoming Vice-Presidents H. R. Fritz, J. A. McDonald, J. R. North, C. S. Purnell, J. G. Tarboux; incoming Director A. G. Dewars.

AIEE Officers Announced for Terms Starting August 1

At the Annual Meeting of the Institute held on June 12, 1950, during the AIEE Summer and Pacific General Meeting in Pasadena, Calif., the Committee of Tellers reported the following results of ballots cast by the membership for the election of officers for terms beginning on August 1, 1950:

President (1-year term)

Titus G. LeClair, Commonwealth Edison Company, Chicago, Ill.

Vice-Presidents (2-year term)

J. G. Tarboux, Cornell University, Ithaca, N. Y.

C. S. Purnell, Westinghouse Electric Corporation, New York, N. Y.

J. R. North, Commonwealth Services, Inc., Jackson, Mich.

H. R. Fritz, Southwestern Bell Telephone Company, St. Louis, Mo.

J. A. McDonald, General Electric Company, Salt Lake City, Utah

Directors (4-year term)

Walter J. Barrett, New Jersey Bell Telephone Company, Newark, N. J. (re-election)

A. G. Dewars, Northern States Power Company, Minneapolis, Minn.

Victor Siegfried, American Steel and Wire Company, Worcester, Mass.

Treasurer (1-year term)

W. I. Slichter, Columbia University, New York, N. Y. (re-election)

Royal W. Sorensen Fellows Organized in Los Angeles

The first annual dinner meeting of The Royal W. Sorensen Fellows was held at the Oakmont Country Club in Glendale, Calif., on June 10, 1950. The Royal W. Sorensen Fellows is a new organization for gathering the men of accomplishment in the Los Angeles Section of AIEE together for an annual meeting to become better acquainted and united in the cause of establishing more esteem for those who have attained Fellowship in AIEE.

Only Fellows of the Los Angeles Section are members of The Royal W. Sorensen Fellows and all are automatically considered members. Dr. Robert A. Millikan, Honorary Member 1933 of AIEE, is Member with Distinction of The Royal W. Sorensen Fellows.

Dr. Royal W. Sorensen has been appointed Honorary President of the new organization.

Third Electronic Instrumentation Conference to Be Held in N. Y.

Final dates for the Third Annual Joint AIEE/IRE Conference on Electronic Instrumentation in Nucleonics and Medicine have been set as October 23–25, 1950. Location of this meeting, which will feature technical papers and discussions on the various problems in instrumentation for the vital fields of nuclear and medical science, is the Park Sheraton Hotel, New York City.

This is the third annual gathering of its type to be sponsored jointly by AIEE and the Institute of Radio Engineers. More than 760 persons attended the highly successful three-day gathering last year at which papers were presented covering the non-nucleonic phases of electronics in medicine, nucleonics in medicine, and nucleonic developments in industry and government.

Such great interest was evoked by the papers presented that they were compiled and published in the form of a consolidated pamphlet covering the proceedings of the conference. This publication (No. S-33) is available from AIEE Order Department, 33 West 39 Street, New York 18, N.Y., at $3.50 per copy. This year's meeting will be held along the same lines and a similar type of publication is contemplated.

Interesting and informative exhibits of instruments and related products will be displayed by leading companies in the field. Those attending the meeting will have an opportunity to see many of the devices (some in actual operation) which will be discussed in the technical papers.

A detailed listing of papers and speakers will be released shortly.

The following are the chairmen of the various committees of the conference: Planning Committee, G. W. Dunlap; Technical Committee, David Langmuir; Publication Committee, Edward M. Bridge; Local Arrangements Committee, R. L. Schoenfeld; Publicity Committee, E. E. Grazda; and Finance Committee, J. H. Mulligan, Jr.

Lamme Medal Nominations to Be Submitted by December 1

Members of the Institute again are reminded that they have an opportunity to submit nominations for the 1950 AIEE Lamme Medal. All nominations must be received not later than December 1, 1950.

Details regarding qualifications for the medal were published in the June 1950 issue of *Electrical Engineering*, page 566.

Penn State Student Branches Complete Successful Program

With an "Engineering Open House" on May 13 as a highlight, the Joint Student Branches of the AIEE and the Institute of Radio Engineers at the Pennsylvania State

College announce the completion of a very successful spring program. During the Open House guests visited the laboratories of the School of Engineering and saw something of the work of the faculty and students.

Also featured on the year's program were the dinner on May 2 at the Nittany Lion Inn which was attended by 115 students and faculty and their companions and addressed by Dean E. B. Stavely, and the inspection trip to the Pennsylvania Power and Light Company's steam electric station at Sunbury, Pa., attended by 200 students and 12 professors. Other activities included trips to the Bell Telephone Company at Bellefonte, the Sylvania plant at Emporium, and the Westinghouse Electric Corporation plant at Sharon, Pa.

AIEE to Participate in ISA Conference and Exhibit

The AIEE is planning to participate in the Instrument Society of America Conference and Exhibit which will be held in the Memorial Auditorium, Buffalo, N. Y., September 18–22, 1950. The program for the AIEE portion of the meeting is given in the following.

Tuesday, September 19, 12:30 p.m.

Joint luncheon and technical meeting with The American Society of Mechanical Engineers.

Luncheon speaker will be Dr. C. C. Furnas, Director, Cornell Aeronautical Laboratory. The technical session will present the following papers:

"Compressibility Effects on Servomechanisms"

"Electric Contacts for Instruments"

"The Vector Meter"

Wednesday, September 20, 2:30 p.m.

AIEE Electrical Instruments and Measurements Session.

The following papers will be presented: "Portable Harmonic Generators," Anson A. Emmerling, General Electric Company, Schenectady, N. Y.

"High-Speed Monitoring of Process Variables," W. E. Belcher, Minneapolis-Honeywell Regulator Company, Philadelphia, Pa.

"Transient Recording Cathode-Ray Oscillograph," Douglas R. Maure, General Electric Company, Schenectady, N. Y.

"Wiresonde Telemetering," Paul R. Goudy, H. F. Colvin, III, Square D Company, Milwaukee, Wis.

Thursday, September 21, 12:30 p.m.

AIEE Luncheon and Technical Meeting. Luncheon is sponsored by the AIEE Niagara Frontier Section with the Section Chairman, Berton Rice, as toastmaster. Speaker at the luncheon will be Rob Roy McCloud, Niagara Mohawk Power Company.

The following papers have been scheduled for presentation at the technical meeting: "Central Instrumentation System for Rocket Laboratory," Frank A. Friswold, Lewis Flight Propulsion Laboratory, National Advisory Committee for Aeronautics, Cleveland, Ohio.

"The Quality Control Indicator," Charles J. Falk, General Electric Company, Schenectady, N. Y.

"Multipoint Tabulating Temperature Recorder," F. A. Harshberger, Westinghouse Electric Corporation, Springfield, Mass.

The AIEE also will maintain a booth at the exhibit which will feature the various publications and other information concerning the Institute. The booth, number 327, will be manned by local Section members.

Electronic Components Report Obtainable From Washington

Additional copies or post-conference orders for the bound Report, containing papers and discussions presented at the Joint AIEE/IRE/RMA Conference on Improved Quality Electronic Components, may now be obtained from the Trielectro Company, 1 Thomas Circle, Washington 5, D. C., at $3.50 per copy. This supersedes the announcement in the July issue of *Electrical Engineering* page 649.

1951 Winter General Meeting Committee. Complete personnel for the 1951 Winter General Meeting have been announced. They are: G. J. Lowell (Chairman), W. J. Barrett, D. T. Braymer, J. B. Harris, Jr., C. T. Hatcher, N. S. Hibshman, G. T. Minasian, C. S. Purnell, D. W. Taylor, J. D. Tebo, and C. H. Willis. The meeting will be held in New York, N. Y., January 22–26.

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Note. Because of the changeover in committee personnel, no items on committee activities are included in this issue.

AIEE PERSONALITIES . . . . .

G. R. Henninger (A '22, F '43), Editor of *Illuminating Engineering* and Director of Publications, Illuminating Engineering Society, New York, N. Y., has joined the staff of Iowa State College, Ames, as a professor in the extension department of the engineering division. His experience and interests in the field will be utilized in building up electrical engineering activities in the engineering extension service. Mr. Henninger is a graduate of the University of Southern California and started his career with the Westinghouse Electric Corporation, Pittsburgh, Pa., where he was engaged in design and development of relay equipment. Later he became a member of the staff of the California Edison Company. His first editorial position was with McGraw-Hill as associate editor of *Electrical West.* In 1931, he became associate editor of *Electrical Engineering* and from 1933 to 1948 was editor of *Electrical Engineering.* In 1942, he served as a civilian consultant to the Secretary of the Navy. Mr. Henninger was later commissioned a lieutenant colonel in the Army of the United States and served as a technical publications officer at Wright Field, Dayton, Ohio.

F. E. Sanford (A '28, F '46), Engineering Consultant, Line Material Company of South Milwaukee, Wis., is the new president of Eta Kappa Nu Association, electrical engineering honor society. Mr. Sanford was formerly vice-president of Eta Kappa Nu. He is a member of the AIEE Charles Le Geyt Fortescue Fellowship Committee. **O. W. Eshbach** (A '17, F '37), Dean of Engineering, Northwestern University, Evanston, Ill., is the new vice-president. **E. T. B. Gross** (A '34, F '48), Professor of Power Systems Engineering, Illinois Institute of Technology, Chicago; **C. B. Holt, Jr.** (A '37, M '44), Associate Professor of Electrical Engineering, Pennsylvania State College, State College, Pa.; **E. B. Kurtz** (A '20, F '29), Professor and Head of the electrical engineering department, University of Iowa, Iowa City; **T. W. Williams** (A '40), Senior Staff Engineer, Bell Telephone Company of Pennsylvania, Philadelphia; and **Robin Beach** (A '15, F '35), Head of Firm, Robin Beach—Engineers Associated, Brooklyn, N. Y. have been elected to the national advisory board of Eta Kappa Nu. Mr. Gross is serving the Institute as a member of the Student Branch Counselors Committee and the Relay Committee. Mr. Beach is a member of the AIEE Safety Committee, an AIEE representative on the National Fire Waste Council, and an alternate AIEE representative on the National Fire Protection Association Electrical Committee. Mr. Beach and Mr. Williams are past presidents of Eta Kappa Nu.

R. W. Sorensen (A '07, F '19, Member for Life), Professor of Electrical Engineering, California Institute of Technology, Pasadena, Calif., has been appointed professor emeritus beginning September 1, 1950, and will continue teaching during the next academic year on a part-time basis. Dr. Sorensen's former students recently set up the Royal W. Sorensen Fellowship in Electrical Engineering at California Institute of Technology. (See page 853 of this issue.) Dr. Sorensen is a past president of AIEE (1940 to 1941) and has been active in Institute affairs. He is at present serving the Institute on the following committees: Code of Principles of Professional Conduct, Past Presidents, Members-for-Life Fund, Professional Division Advisory, and Registration of Engineers. Dr. Sorensen is also a member of the Engineers Joint Technical Society of Los Angeles, Calif., Sigma Xi, and Tau Beta Pi.

A. B. Smith (A '04, F '22, Member for Life), Vice-President, Automatic Electric Laboratories, Inc., Chicago, Ill., was recently awarded the honorary degree of Doctor of Engineering by the University of Nebraska in recognition of his contributions in the field of communications. In 1926, Dr. Smith received the degree of Doctor of Philosophy in Physics from Northwestern University. He is serving the Institute as a member of the following committees: Award of Prizes, Committee on Safety, Communication Switching Systems, and Wire Communication Systems. Dr. Smith holds membership in a number of professional engineering and scientific societies.

D. W. Nethercut (M '37, F '45), System Planning Engineer, Central Engineering Department, and **L. F. Ferri** (A '31, M '37), Electrical Engineer, Central Engineering Department, Ohio Public Service Company, Elyria, have both joined Commonwealth Services Inc., Jackson, Mich. Mr. Nethercut will be engaged as a system planning engineer with Commonwealth Services. Mr. Nethercut is serving the Institute as a member of the Transmission and Distribution Committee and Mr. Ferri is a member of the AIEE Committees on Relays and Carrier Currents.

W. S. Hill (A '25, F '50), Vice-President, Engineering, Locke, Inc. (a General Electric Company affiliate), Baltimore, Md., has joined the General Electric Company's Apparatus Department as manager of the Commercial Engineering Division of the Transformer and Allied Products Divisions at Pittsfield, Mass. Mr. Hill has been with General Electric since 1923 and was named Vice-President in 1948. He is serving the Institute as a member of the following committees: Professional Division Advisory, Planning and Co-ordination, and the Committee on Constitution and By-Laws.

Rawson Bennett II (A '38, M '45), Commanding Officer and Director, United States Navy Electronics Laboratory, San Diego, Calif., has been assigned to the Armed Services Industrial College in Washington, D. C. Captain Bennett had been director of the laboratory since 1946. He holds the Navy Department's Legion of Merit Award for his contributions to varied developments in the military field of submarine detection. Captain Bennett is a Fellow of the Institute of Radio Engineers and the Acoustical Society of America.

G. W. Hart (A '31), Manager of Market Research, General Electric Company, has been appointed manager of advertising, sales promotion, and sales training of the company's air conditioning department in Bloomfield, N. J. Prior to joining General Electric, Mr. Hart had been with the management consultant firm of Booz, Allen, and Hamilton, New York, N. Y., and had also been associated with the Consolidated Edison Company of New York and Ebasco Services, Inc., New York, N. Y.

J. A. Hutcheson (M '44), Director of Research, Westinghouse Electric Corporation, Pittsburgh, Pa., has been named chairman of the Committee on Ordnance of the Research and Development Board. Dr. Hutcheson joined Westinghouse in 1926 and has been director of research since 1948. During 1932 and 1933, he designed the modulation system for the 500-kw radio broadcasting transmitter at *WLW*, Cincinnati, Ohio, then the most powerful of its kind in the world.

A. K. Bushman (M '26, F '47), Manager, Application, Service, and Construction Engineering Divisions, General Electric Company, Schenectady, N. Y., has been appointed manager of industry divisions in the sales organization of the company's Apparatus Department. Mr. Bushman joined General Electric in 1915 and, in 1945, he was appointed manager of the Application, Service, and Construction Engineering Divisions.

J. A. Green (A '42, M '49), Head of the Broadcast Engineering Department, Collins Radio Company, Cedar Rapids, Iowa, has established the John A. Green Company, manufacturers' representatives, and the Equipment and Service Company, consulting engineers and electrical manufacturers, at Dallas, Tex. Mr. Green had been associated with Collins Radio Company for nine years.

L. A. Pagano (A '26), Assistant Engineer, Electrical Engineering Department, Consolidated Edison Company of New York (N. Y.), Inc., has been appointed engineering consultant attached to the sales department of the Utilities and Industrial Division of the Sangamo Electric Company, Springfield, Ill. Mr. Pagano had been associated with Consolidated Edison for 29 years.

E. L. White (M '37, F '47), Chief, Aviation Division, Bureau of Engineering, Federal Communications Commission, Washington, D. C., has been appointed Chief of the Safety and Special Radio Services Bureau of the Federal Communications Commission. Mr. White is a member of the Institute of Radio Engineers and the Society of American Military Engineers.

W. S. Ginn (A '37, M '49), Assistant Sales Manager, Transformer and Allied Products Divisions, General Electric Company, Pittsfield, Mass., has been appointed manager of sales for the divisions. Mr. Ginn joined General Electric in 1936 and during World War II he served with the United States Navy. He was appointed assistant sales manager in 1949.

H. J. MacLeod (A '23, F '45), Professor and Head of the Department of Mechanical and Electrical Engineering, University of British Columbia, Vancouver, Canada, has been appointed Dean of Applied Science. Dr. MacLeod has been head of the department of mechanical and electrical engineering since 1936. He was formerly with the University of Alberta.

C. T. Button (A '26, M '46), Vice-President in Charge of Sales, Howell Electric Motors Company, Howell, Mich., has been appointed director of sales for Holtzer-Cabot (division of National Pneumatic Company, Inc.). Mr. Button was formerly with Holtzer-Cabot for 18 years as assistant sales manager of the electric motor division.

OBITUARY

Carlo Prestbye Christensen (A '14, Member for Life), Director of Power, Boulder Canyon Project, United States Bureau of Reclamation, Boulder City, Nev., died June 16, 1950. Mr. Christensen was born in Helena, Mont., on May 4, 1885, and was graduated from Stanford University with an electrical engineering degree in 1911. In 1911, he joined the Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation) in East Pittsburgh, Pa., and after one year with the company, he accepted a position with the Great Western Power Company of Sacramento, Calif. During succeeding years, Mr. Christensen was employed by leading mining and power companies in California and Montana, including such firms as Stone and Webster Construction Company, Anaconda Copper Mining Company, and the San Joaquin (Calif.) Light and Power Corporation. In 1921, he joined the Southern California Edison Company on the staff of its Big Creek plant. When this plant was completed, he was transferred to the company's Los Angeles, Calif., office, where he remained until 1930. Mr. Christensen then became chief field engineer for the Western Precipitation Company, and in 1933, he became test engineer for the Metropolitan Water district during construction of its transmission lines and substations for the Colorado River aqueduct. Upon completion of this work, he joined the Bureau of Reclamation and was in direct charge of the installation of much of the generating equipment in the Boulder Dam power plant. In 1940, Mr. Christensen was transferred to Grand Coulee, where for four years he was in charge of the installation of power units at that plant. He was a past chairman of the Boulder City Subsection of AIEE.

Arthur Henry Timmerman (A '03, M '10, F '12, Member for Life), retired, died July 18, 1950. Mr. Timmerman had just recently retired as vice-president and a director of the Wagner Electric Corporation, St. Louis, Mo. He was born on May 1, 1871, in New York, N. Y., and was graduated from the City College of New York in 1891 with a Bachelor of Science degree. He then entered Cornell University and received the degrees of Mechanical Engineer in Electrical Engineering in 1892 and Master of Mechanical Engineering in 1893. From 1893 to 1894, Mr. Timmerman was an instructor in electrical engineering at Washington University, St. Louis, and from 1894 to 1899, he was a professor of physics in charge of electrical engineering at the School of Mines and Metallurgy of the University of Missouri, Columbia. Mr. Timmerman's industrial career began in 1899, when he joined the Wagner Electric Corporation. He was chief engineer from 1908 to 1919 and, in 1919, he became vice-president. In 1925, he was elected a director of the company. Mr. Timmerman retired in March of 1950. He had served the Institute as a member of the following committees: Industrial and Domestic Power (1919–20), Standards (1919–22), and Electrical Machinery (1924–25). Mr. Timmerman was active in organizations for improving the standards of the electrical industry. He helped form the American Association of Electric Motor Manufacturers in 1908. When this organization broadened its scope and changed its name to the Electric Power Club in 1910, Mr. Timmerman served on its Board of Governors and was elected its president in 1923. When this organization and the Associated Manufacturers of Electrical Supplies combined in 1926 to form the National Electrical Manufacturers Association, he was elected to its Board of Governors and served until 1928. He was also active in the National Metal Trades Association and was a member of the Society of Automotive Engineers.

MEMBERSHIP • • • •

Recommended for Transfer

The Board of Examiners at its meeting of July 20, 1950 recommended the following members for transfer to the grade of membership indicated. Any objections to these transfers should be filed at once with the secretary of the Institute. A statement of valid reasons for such objections must be furnished and will be treated as confidential.

To Grade of Fellow

Billau, L. S., elec. engr., Baltimore & Ohio R. R. Co., Baltimore, Md.
Brown, J. S., elec. station engr., Duquesne Light Co., Pittsburgh, Pa.
Burns, H. R., mgr., genl. engg. dept., The Cincinnati Gas & Electric Co., Cincinnati, Ohio.
Ericson, R. C., supervising test & relay engr., Northern Indiana Public Service Co., Hammond, Ind.
Farrar, C. L., chairman & prof. elec. engg., University of Oklahoma, Norman, Okla.
Heidenreich, G. E., Sr., elec. engr., The Cincinnati Gas & Elec. Co., Cincinnati, Ohio.
Hieronymus, T. G., pres., Radiation Laboratories, Inc., Kansas City, Mo.
Hitchcock, L. W., prof. & head, elec. engg. dept., University of New Hampshire, Durham, N. H.
Jarvis, K. W., mgr., electronics dept., Automatic Electric Co., Chicago, Ill.
Stanford, A. G., vice-pres., Robert & Co., Associates, Atlanta, Ga.
Stout, M. B., elec. engg. professor, University of Michigan, Ann Arbor, Mich.

11 to grade of Fellow

To Grade of Member

Alsaker, A. K., asst. to chief engr., Delta Star Electric Co., Chicago, Ill.
Apostol, S. D., circuit planning engr., Commonwealth Edison Co., Chicago, Ill.
Blashfield, W. H., engr., North Electric Manufacturing Co., Galion, Ohio.
Bowman, P. G., engr., General Electric Co., Minneapolis, Minn.
Bragg, A. D., mgr., apparatus dept., General Electric Co., San Francisco, Calif.
Brunzell, G. M., division supt., Washington Water Power Co., Spokane, Wash.
Burkhart, G. N., Jr., asst. chief engr., Duncan Electric Mfgr. Co., Lafayette, Ind.
Bushnell, R. J., asst. supt., service & meter dept., Commonwealth Edison Co., Chicago, Ill.
Carlberg, H. A., supt., elec. div., Hanford Works, General Electric Co., Richland, Wash.
Carter, B. H., elec. designer, Sanitary Dist. of Chicago, Chicago, Ill.
Cohn, G. I., asst. prof., elec. engg., Illinois Institute of Technology, Cambridge, Mass.
Connelly, B. J., vice-pres., genl. mgr., Minerallac Electric Co., Chicago, Ill.
Conover, W. B., engr., General Electric Co., Pittsfield, Mass.
Crosthwait, G. N., div. engr., Texas Electric Service Co., Wichita Falls, Tex.
Crouch, C. A., telegraph system engr., Atchison, Topeka & Santa Fe Ry. Co., Chicago, Ill.
David, T. H., Jr., mgr. commercial engg. div., Hotpoint, Inc., Chicago, Ill.
Davis, M. F., chief, electronic research subdivision, Naval Ordnance Laboratory, Silver Spring, Md.
Eggert, W. C., elec. engr., City & County of San Francisco, San Francisco, Calif.
Ewald, L. J., exchange transmission engr., Illinois Bell Tel. Co., Chicago, Ill.
Forsberg, E. J., planning engr., Northern States Power Co., Minneapolis, Minn.
George, G. R., asst. to transmission & distribution supt., The Washington Water Power Co., Spokane, Wash.
Gill, H. W., industrial engr., General Electric Co., Dallas, Tex.
Girdwood, A. J., chief engr., Leland Electric Canada, Ltd., Guelph, Ontario, Canada
Grethel, B. W., elec. engr., San Francisco Public Utilities Commission, San Francisco, Calif.
Gruven, V. W., field engr., Stanley Engineering Co., Muscatine, Iowa.
Hattrup, H. E., assoc. prof. elec. engg., University of Idaho, Moscow, Idaho.
Hoffman, H. P., research engr., aero physics lab., North American Aviation, Inc., Downey, Calif.
Hummer, J. L., asst. prof. elec. engg., Rhode Island State College, Kingston, R. I.
Huss, P. O., assoc. prof., elec. engg. dept., The University of Akron, Akron, Ohio.
Keller, A. C., director, switching apparatus dev., Bell Tel. Laboratories, New York, N. Y.
King, E. F., engg. lecturer, University of California, Los Angeles, Calif.
Knierim, R. V., assoc. elec. engr., div. of architecture, State of California, Sacramento, Calif.
Kodil, C. E., senior elec. engr., dept. water & power, City of Los Angeles, Calif.
Kotnik, E. F., engg. designer, Consolidated Vultee Aircraft Corp., San Diego, Calif.
Kramar, D. G., supervising designer, Pacific Gas & Electric Co., San Francisco, Calif.
Ledermann, W., elec. engr., Sargent & Lundy, Chicago, Ill.
Leitzke, V. A., application engr., General Electric Co., Buffalo, N. Y.
Lewis, L. J., assoc. prof. elec. engg., University of Washington, Seattle, Wash.
Livingstone, T. A., test engr., The Okonite-Callender Cable Co., Inc., Paterson, N. J.
Lowery, W. T., asst. chief engr., The Toledo Edison Co., Toledo, Ohio.
Macdonald, C. L., project engr., Gibbs & Hill, Inc., New York, N. Y.
Maiers, M. J., mgr., sales service dept., Commonwealth Edison Co., Chicago, Ill.
Maloney, C. W., elec. engr., Stone & Webster Engg. Corp., Boston, Mass.
Marsten, J., vice-pres., International Resistance Co., Philadelphia, Pa.
McCloskey, J. W., asst. engr., Consolidated Edison Co. of N. Y., Inc., New York, N. Y.
Miller, D. L., research engr., North American Aviation, Inc., Los Angeles, Calif.
Monell, F. B., Jr., member technical staff, Bell Telephone Labs., Inc., Murray Hill, N. J.
Motter, D. P., design engr., General Electric Co., Fort Wayne, Ind.
Munson, H. J., vice-pres., The Tide Co., Tacoma, Wash.
O'Connor, J. J., asst. editor, *Power*, McGraw Hill Publishing Co., New York, N. Y.
Ogle, H. M., section engr., General Electric Co., Schenectady, N. Y.
Pann, S. G., elec. engr., dept. water & power, City of Los Angeles, Calif.
Perry, R. H., engr., Commonwealth Edison Co., Chicago, Ill.
Peterson, R. A., elec. designer, Pioneer Service & Engineering Co., Chicago, Ill.
Pharmer, W. L., district mgr., Sterling Electric Motors, Inc., Philadelphia, Pa.
Phelps, B. E., senior engr., International Business Machines Corp., Poughkeepsie, N. Y.
Phillips, W. E., section head, engg. dept., Leeds & Northrup Co., Philadelphia, Pa.
Platt, N. L., partner, St. John & Platt, Consulting Engineers, Binghamton, N. Y.
Randle, R. O., asst. design engr., Houston Lighting & Power Co., Houston, Tex.
Ratcliffe, L. C., toll & transmission engr., Bell Telephone Co. of Canada, Toronto, Ontario, Canada
Ridenhour, W. L., senior engr., Safe Harbor Water Power Corp., Baltimore, Md.
Ridgway, W., field technical engr., General Electric Co., San Francisco, Calif.
Robinson, R. R., mgr., board of public works, Electric Water Sewage Disposal, Niles, Mich.
Rule, B. H., project engr., California Institute of Technology, Pasadena, Calif.
Rydbeck, V. A., transmission & distribution div., General Electric Co., Schenectady, N. Y.
Ryder, C. V., engr., switchgear div., Canadian Westinghouse Co., Hamilton, Ontario, Canada
Scheerer, P. J., elec. engr., Monongahela Power Co., Fairmont, W. Va.
Scheiber, E. J., chief, electrical design section, Bureau of Reclamation, Sacramento, Calif.
Schullerts, F. B., asst. engr., Pacific Gas & Electric Co., San Francisco, Calif.
Short, W. G., cable specialist, General Electric Co., New York, N. Y.
Stopps, L. G., transformer engr., Canadian Westinghouse Co., Hamilton, Ontario, Canada
Tarr, A. B., Jr., outside plant engr., Mountain States Tel. & Tel. Co., Denver, Colo.
Tashjian, G. K., elec. engr., Cincinnati Gas & Electric Co., Cincinnati, Ohio.
Turbyfill, O. B., supervising engr., inventory control div., Commonwealth Edison Co., Chicago, Ill.
Van Sickle, M. E., asst. chief local system operator, Pennsylvania Power & Light Co., Harrisburg, Pa.
VanValkenburg, H. E., elec. research engr., Sperry Products Inc., Danbury, Conn.
Vinogradov, N. A., senior system control engr., Shanghai Power Co., Shanghai, China
Ward, R. I., engr., Commonwealth Edison Co., Chicago, Ill.
Watson, R. W., elec. engr., Middle West Service Co., Chicago, Ill.
Welch, G. H., asst. genl. mgr., motor & control div., Westinghouse Electric Corp., Buffalo, N. Y.
Williams, J. B., elec. designer, Pioneer Service & Engineering Co., Chicago, Ill.
Willson, E. A., asst. to mgr. power prod. & system operation, Northern States Power Co., Minneapolis, Minn.
Zamsky, J., elec. engr., Allis-Chalmers Co., Milwaukee, Wis.
Ziegenfuss, H. E., engr., Consolidated Gas Electric Light & Power Co., Baltimore, Md.

84 to grade of Member

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member, have been received from the following candidates, and any member objecting to election should so notify the Secretary before September 25, 1950, or November 25, 1950, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Fellow

Fry, T. C., Bell Tel. Labs., Inc., New York, N. Y.

1 to grade of Fellow

To Grade of Member

Bloecker, W. E., American Tel. & Tel. Co., New York, N. Y.
Bothwell, F. E., Northwestern Univ., Evanston, Ill.
Chatting, A. H., E. B. Badger & Sons (G. B.) Ltd., London, England
Davies, R. H., Ferranti Elec., Inc., New York, N. Y.
Ellett, E. V., Westinghouse Elec. Corp., Buffalo, N. Y.
Gilman, G. W., Bell Tel. Labs., Inc., New York, N. Y.
Gravel, A. L., Bell Tel. Co. of Canada, Montreal, Quebec, Canada
Hennessey, R. G., Fairchild Camera & Instrument Corp., Jamaica, N. Y.
Hewett, J. K., Corps. of Engg., Omaha, Nebr.
Kukutschka, E. J. (re-election), Cia. Productora de Carburo de Calcio, S. A., Mexico, D. F., Mexico
Mann, J. W., Northwest Syndicate, Inc., Tacoma, Wash.
Morrison, D., Paragon Elec. Co., Two Rivers, Wis.
Morse, D. B., Bendix Aviation Corp. of Sidney, N. Y., Burbank, Calif.
Pagay, N. M., Madhya Bharat Elec. Supply, Ujjain, India
Petersen, C. A., Elliott Co., Ridgway, Pa.
Raghavan, V. R., Central Electricity Comm., Simla, India
Rezos, G., Pacific Tel. & Tel. Co., San Francisco, Calif.
Ries, E. P., Shell Chemical Corp., Pittsburg, Calif.
Roy, J. J., Aira Sugar Factory, Kheri-Lakhimpur, U. P., India
Sankaran, K. M., Central Electricity Comm., Simla, India
Schabtach, C., General Elec. Co., Schenectady, N. Y.
Schimpf, R. G., Dr. Eugene Mittelmann Consulting Engr., Chicago, Ill.
Tanabe, S. (re-election), Saito Industrial Co. Ltd. & Yokohama Foreign Trade Inst., Tokyo, Japan
Taylor, J. A., Jr., General Elec. Co., Oklahoma City, Okla.
Todd, S. R., 457 North Racine Ave., Chicago, Ill.
Unk, J. M., Philips Telecommunications, Hilversum, Holland
Watkins, J. H., Jr., Slaughter, Saville & Blackburn Inc., Richmond, Va.

27 to grade of Member

OF CURRENT INTEREST

Industrial Electronics to Be Featured at 1950 National Electronics Conference

The Sixth Annual National Electronics Conference will be held at the Edgewater Beach Hotel in Chicago, Ill., on September 25, 26, and 27, 1950. The conference is sponsored by the Illinois Institute of Technology, Northwestern University, the University of Illinois, AIEE, and the Institute of Radio Engineers, with the University of Wisconsin and the Society of Motion Picture and Television Engineers participating.

The regular fall meeting of the AIEE Committee on Electronics will be held in Chicago during the time of the conference. W. G. Dow, Chairman of this committee, is the AIEE representative on the Board of Directors of the National Electronics Conference.

The National Electronics Conference, which is a nonprofit corporation, was organized in Chicago in 1944 to provide a "National Forum for the presentation of authoritative technical papers on Electronic Research, Development, and Application." Not only does the conference supply a medium through which technical papers can be presented but it also provides for open discussion on the part of those in attendance at the session at which the papers are presented. The conference also sponsors an educational exhibit so that those in attendance are kept abreast of the latest technical advances in electronics.

Registration at the conference is open to anyone interested in the various phases of electronics. Society affiliation is not required.

The program this year is slanted heavily toward industrial electronic applications. The papers to be presented at the technical sessions are as follows:

Monday, September 25

10:00 a.m. Microwaves and Antennas

Corrugated End-Fire Antennas, *D. K. Reynolds, W. S. Lucke,* Stanford Research Institute

New Techniques in Microwave Spectroscopy. *W. E. Good,* Westinghouse Research Laboratories

Properties of Longitudinal Slots in Circular Waveguides. *G. E. Feiker, S. C. Clark, Jr.,* General Electric Company

10:00 a.m. Magnetic Amplifiers

Magnetic Amplifier Voltage Regulator. *J. L. Wolff,* Westinghouse Electric Corporation

Noise Figure of the Magnetic Amplifier. *N. R. Castellini,* Signal Corps Engineering Laboratories

Magnetic Amplifiers With Orthonol Tape Cores. *W. A. Geyger,* Naval Ordnance Laboratory

10:00 a.m. Dielectric Heating

Dielectric Load Tuning in RF Heating. *R. H. Hagopian,* Westinghouse Electric Corporation

Measuring Dielectric Properties During HF Heating. *Eugene Mittelman,* Consulting Engineer, Chicago, Ill.

2:00 p.m. Time-Position Measurement

The Electronic Umpire. *R. F. Shea,* General Electric Company

Thyratrons as Close-Differential Relays. *J. J. Baruch,* Massachusetts Institute of Technology

Electromechanical Pulse Delay Unit. *J. F. Gordon,* Bendix Radio Company

2:00 p.m. Circuits

Miniaturizing Pentode Amplifiers by Positive Feedback. *W. B. Anspacher,* Naval Ordnance Laboratory

Using Conductance Curves in Electronic Circuit Design. *K. A. Pullen,* Aberdeen Proving Ground, Md.

Analysis of Twin-T Filters. *L. G. Gitzendanner,* General Electric Corporation

Cascading Cathode Followers to Provide High Impedance Transformation Ratios. *S. E. Smith, W. J. Kessler,* University of Florida

2:00 p.m. Tube Technology

Electrolytic Tank Studies in Designing High Vacuum Tubes. *J. E. Jacobs,* Engineering Laboratory, General Electric X-Ray Corporation

A Beam-Type That Multiplies. *Alexander Somerville,* Northwestern University

Low-Noise Miniature Pentode for Audio Amplifier Service. *R. A. Wissolick, D. P. Heacock,* RCA Victor Division

Glass Selection and Production Techniques for X-Ray and Other Tubes. *J. B. Gosling,* General Electric Company; *M. J. Zunick,* General Electric X-Ray Corporation

Tuesday, September 26

10:00 a.m. Television

Television in Industrial Applications. *J. A. Good,* Diamond Power Speciality Corporation

Stereo Television in Remote Control. *H. R. Johnston, C. A. Hermanson, H. L. Hull,* Argonne National Laboratory

The Genlock—A New Tool for Better Programming in TV. *J. H. Roe,* RCA Victor Division

10:00 a.m. Inspection and Control

Reliable Electronic Equipment—A Progress Report. *G. B. Devey,* Office of Naval Research

Detection of Tramp Metal. *C. W. Clapp,* General Electric Company

Production Testing Techniques for Metallized Paper Condensers in a Telephone Network. *A. L. Bennett,* Western Electric Company; *G. M. L. Sommerman,* Northwestern University

Selecting Critical Components for Matched Channel Radio Receiving Systems. *H. D. Webb,* University of Illinois

10:00 a.m. Exploration and Navigation

Recent Lorac Developments. *J. E. Hawkins,* Seismograph Service Corporation

Flight Path Control. *D. L. Markusen,* Minneapolis-Honeywell Regulator Company

Radio Interference Blanking Ahead of Receiver. *M. M. Newman, J. R. Stahmann, Edward Svendson,* Lightning and Transients Research Institute

2:00 p.m. Research Instrumentation

The Electron Optical System of a Permanent Magnet Electron Microscope. *J. H. Reisner,* RCA Victor Division

Electronic Scanning Techniques for Low Level Circuits. *B. R. Shepard,* General Electric Company

The Point-Contact Photoconductance Cell. *G. D. O'Neill,* Sylvania Electric Products Company

A Multipurpose D-C Amplifier With Reduced Zero Offset. *Will McAdam, R. E. Tarpley, A. J. Williams, Jr.,* Leeds and Northrup Company

2:00 p.m. Computers

The Study of Oscillator Circuits by Analogue Computer Methods. *Han Chang, R. C. Lathrop, V. C. Rideout,* University of Wisconsin

Rosette Principal Strain Computer. *C. M. Hathaway, R. C. Eddy,* Hathaway Instrument Company

A Versatile Small Analogue Computer. *J. T. Carleton,* Westinghouse Electric Corporation

An Electrical Analogue for Indeterminant Mechanical Structures. *J. P. Corbett, J. F. Calvert,* Northwestern University

2:00 p.m. Electroacoustics

Function of A-C Bias in Magnetic Recording. *R. E. Zenner,* Armour Research Foundation

Recent Design Developments on Electronic Organ Tone Generators. *S. L. Krauss, C. Tennes,* C. G. Conn, Ltd.

Design of Loudspeaker Enclosures. *L. L. Beranek,* Massachusetts Institute of Technology

Wednesday, September 27

10:00 a.m. Oscillography

Progress Report on Millimicrosecond Oscillography. *Y. P. Yu, H. E. Kallman, P. S. Christaldi,* Allen B. DuMont Laboratories, Inc.

A Six-Channel Cathode-Ray Recording Oscillograph. *W. D. Tilton, Jr.,* Hathaway Instrument Company

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Future Meetings of Other Societies

American Chemical Society. Chicago Section—Sixth National Chemical Exposition. September 5–9, 1950, Chicago Coliseum, Chicago, Ill.

American Society of Mechanical Engineers. 19th National Exposition of Power and Mechanical Engineering. November 27–December 2, 1950, Grand Central Palace, New York, N. Y.

American Standards Association. Annual Meeting. November 27–29, 1950, Waldorf-Astoria Hotel, New York, N. Y.

Audio Engineering Society. 2d Audio Fair. October 26–28, 1950, Hotel New Yorker, New York, N. Y.

Hydraulic Institute. September 6–8, 1950, The Drake Hotel, Chicago, Ill.

Institute of Traffic Engineers. Annual Meeting. September 24–27, 1950, Commodore Hotel, New York, N. Y.

Instrument Society of America. 1950 Instrument Conference and Exhibit. September 18–22, 1950, Memorial Auditorium, Buffalo, N. Y.

National Conference on Industrial Hydraulics. Sixth Annual Conference. October 18–19, 1950, Sherman Hotel, Chicago, Ill.

National Electrical Manufacturers Association. November 13–16, 1950, Chalfonte-Haddon Hall, Atlantic City, N. J.

National Electronics Conference. September 25–27, 1950, Edgewater Beach Hotel, Chicago, Ill.

National Research Council. 1950 Conference on Electrical Insulation. November 1–3, 1950, Pocono Manor Inn, Pocono Manor, Pa.

National Safety Congress and Exposition. October 16–20, 1950, Stevens, Morrison, and Congress Hotels, Chicago, Ill.

Society of Automotive Engineers. Transportation Meeting. October 16–18, 1950, Hotel Statler, New York, N. Y.

Society of the Plastics Industry. Annual National Conference. October 18–20, 1950, New Ocean House, Swampscott, Mass.

A Portable Projection Oscilloscope. *Victo Wouk,* Beta Electric Corporation

A Cathode-Ray Oscillograph for Impulse Testing. *W. G. Fockler,* Allen B. DuMont Laboratories, Inc.

10:00 a.m. Control Instrumentation

Nonlinear Techniques for Improving Servo Performance. *Donald McDonald,* Cook Research Laboratories

Electronic Control for Heating Systems. *J. M. Wilson,* Minneapolis-Honeywell Regulator Company

Automatic Control of Inaccessible Terminal Voltages. *R. L. Cosgriff, E. H. Gamble,* Curtiss Wright Corporation

10:00 a.m. Nucleonics

Electronic Aspects of Radiation Instruments. *E. E. Goodale, R. M. Lichtenstein,* General Electric Company

Corona Voltage Regulator Tubes for Nucleonics. *D. L. Collins,* Victoreen Instrument Company

Electronics in Particle Accelerators. *T. M. Dickinson, T. W. Dietze,* General Electric Company

2:00 p.m. Industrial Control

Industrial Electronic Control Design Practices. *E. H. Vedder,* Westinghouse Electric Corporation

Electronics in Electric Power Central Stations. *A. J. Ward,* Sargent and Lundy

An Indirect Method of Process Control. *R. G. Durnal,* Westinghouse Electric Corporation

2:00 p.m. Signal Generators and Analysers

A 20-Mc to 1,000-Mc Sweep Oscillator. *J. E. Ebert, H. A. Finke,* Polytechnic Research and Development Company, Inc.

A Miniature Crystal Controlled S-Band Signal Generator. *W. F. Marshall,* Bendix Radio Company

A High Resolution Spectrum Analyser. *Theodore Miller, D. S. Sims,* Westinghouse Research Laboratories

2:00 p.m. Nucleonics

Radioactive Snow Gauge with Telemetering Systems. *J. A. Doremus,* Motorola, Inc.

Design Characteristics of Air Proportional Counters. *A. C. Scheckler,* General Electric Company

An Investigation of a Scintillation Counter Using Anthracene Crystals. *Bernd Ross,* Radiation Counter Laboratories, Inc.

Hermetically Sealed High-Pressure Ion Chambers. *J. G. Haines,* General Electric Company

To facilitate registration of those attending the National Electronics Conference, advance registration by mail is urged. The $3 registration fee covers all technical sessions. Mail advance registrations to National Electronics Conference, L. W. Matsch, Secretary, Illinois Institute of Technology, 3300 South Federal Street, Chicago 16, Ill.

NSPE Adopts Statement of Principles Regarding Engineers Joining Unions

While the professional provisions of the Taft-Hartley Act have aided considerably in protecting the professional status of employed engineers, in certain instances continuing pressure has been brought to bear on them to seek their economic advancement through unionization rather than through professional means. One of the problems confronting the engineer employee has been the lack of a clear-cut statement regarding his professional responsibilities in relation to union affiliation. The National Society of Professional Engineers, believing that a definite statement of principles on this question would be desirable, formulated such a statement which was adopted by the Board of Directors of that society in June 1950.

STATEMENT OF PRINCIPLES REGARDING COLLECTIVE BARGAINING BY PROFESSIONAL EMPLOYEES

1. It is definitely unprofessional for a professional engineer, professionally employed, VOLUNTARILY to join a heterogeneous labor union, dominated by, or obligated to, nonprofessional groups. As stated by the society, through its Board of Directors at Oklahoma City in September 1948, "The individual responsibility and independent judgment required of a Professional Engineer are incompatible with the regimentation fundamentally inherent in unionization."

Nothing in this statement of principle shall be construed as a criticism of engineers who may be forced to join a labor union, against their will, but engineers in this predicament should seek to extricate themselves by due process of law.

Nothing in this statement of principle shall be construed as a criticism of engineers-in-training, who voluntarily join a labor union when, as a step in their practical engineering training, they are temporarily employed in nonprofessional or subprofessional work, where their fellow workers are organized. When promoted to professional responsibilities, however, the engineer cannot continue his labor union affiliations without sacrifice of professional status.

2. Organizations of professional engineers for collective bargaining, in any form, are to be deplored, although their existence, for the present, may be condoned under certain circumstances.

When engineers are treated collectively by an employer they may be compelled to deal with him on the same basis. Employers should appreciate that engineers have individual capacities and talents which should be considered on an individual basis, that the compensation of an engineer should be in proportion to the value of his services and not based on his age, his degrees, or any other yardstick that can be applied collectively, and that an engineer's working conditions should conform to the nature of his work rather than to any general pattern applicable to employees engaged in routine tasks that are subject to standardization.

When employers generally are persuaded that professional employees must be viewed as individuals and not in groups or classes, then NSPE may condemn collective bargaining by professional engineers, without qualification. In the meantime, we advise the young engineer that the existence of collective bargaining by professional engineers in an industry jeopardizes his professional status. Either the employer fails to appreciate the professional nature of his engineers' work, or the employees themselves are not adhering to professional concepts. Therefore, professional engineers and engineers-in-training should not seek employment where professional engineers, professionally employed, bargain collectively.

In the event that any comments concerning the above Statement of Principles are forthcoming, they should be addressed to the National Society of Professional Engineers, 1121 Fifteenth Street N. W., Washington 5, D. C.

EJC Panel Makes Statement on National Water Policy

Members of the Engineers Joint Council have received copies of the Engineers Joint Council National Water Policy panel statement that has been transmitted to the temporary Water Resources Policy Commission created by Executive Order on January 3, 1950. This statement was solicited by the Commission to provide it with a consensus of the engineering profession on water policy. Following the appearance of the Commission's report, which is due December 1, 1950, the panel plans to prepare a final report, as distinguished from the preliminary statement, based upon a critical examination of the Commission's findings. To this end, all its committees are being held intact until its report has been completed.

The National Water Policy statement represents the carefully considered thinking of 80 engineers from all branches of the profession. It is one of the very few truly collaborative projects ever undertaken by the profession on such a large scale. Perhaps it is inappropriate to attempt to place a monetary value on this document, but Chairman Horner has calculated it is worth at least $150,000 in terms of personal time and expense. The most striking thing about it has been the complete unanimity of agreement on the principles involved. Although this group cannot claim to speak for the whole profession, because it was created by the Engineers Joint Council out of its constituent membership, the uniform thinking of this diverse group of professional men is reasonable evidence that it does so.

The statement was assembled too rapidly to include the detailed analysis of each point that would have been desirable, but a wealth of supporting data have been accumulated and are being reserved by the Task Committee chairmen. When the Presidential Commission was appointed, the panel was faced with the choice of gathering a statement by the profession as a guide to the Commission, or of waiting until the report was issued and then attacking it at points of disagreement. The panel chose the former course, even though this required developing a large organization very rapidly and would not permit as broad a study as had originally been intended.

The competition among Federal agencies to spend public money apparently causes great waste. The agencies are not wholly to blame, however, because they are abetted by the Administration and by most of the Congress. It has been impossible to include more than a sampling of Federal extravagance in the Water Policy statement, but it might be pointed out that the current Rivers and Harbors Bill authorizes more money than the total similarly authorized for such purposes over the whole history of the country through 1947. Those who have studied the bill state that much of it is completely indefensible by any standard.

The seriousness of the questions covered in the Water Policy statement is so great, and so much earnest effort has been expended in preparing it, that the panel hopes it will be read and discussed as widely as possible. Arrangements are being made for suitable publicity designed to reach the layman but this will not be enough. The matter is so important that provision should be made for discussion at local section meetings. This might be done by recommending appointment of small local groups to study the document and present significant features of it to local sections. Alternatively, interested persons might be asked to address local sections on the subject.

Copies of the statement can be obtained from the Engineers Joint Council, 29 West 39th Street, New York 18, N. Y., for $1.50.

This comment has been prepared for the Engineers Joint Council to urge careful consideration of the document in question and to ask for help in gaining it the broad attention it is believed to deserve.

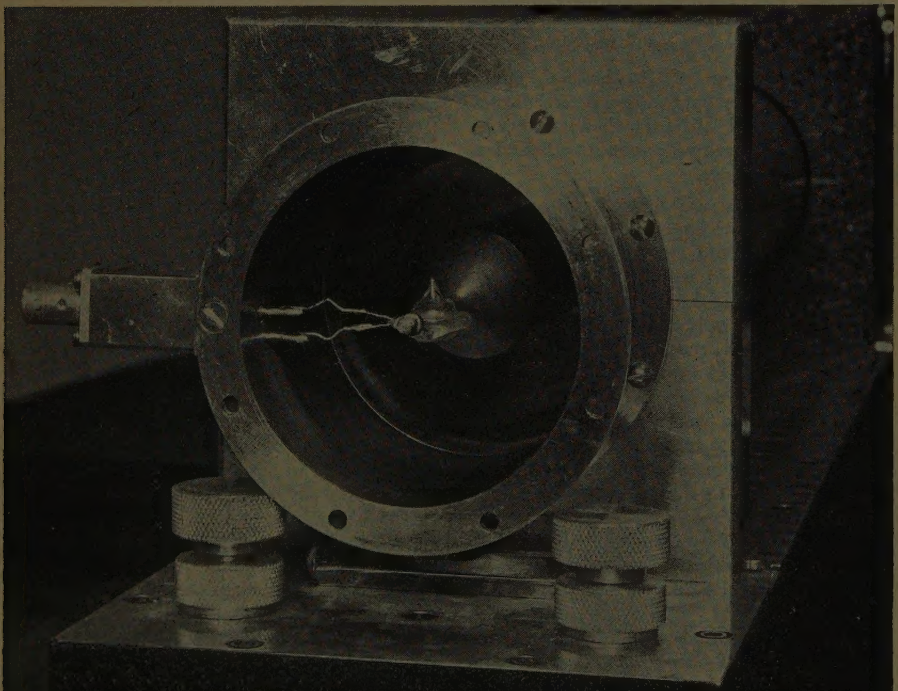
NBS Develops Electrodynamic Ammeter for VHF Measurements

In establishing standards for electric circuits in the very-high-frequency region used by radio and television services it is important to extend the direct measurement techniques used at lower frequencies as far as possible. Up to 300 megacycles, the current flowing in a circuit whose physical dimensions are small with respect to wavelength is essentially a uniform quantity and the electric characteristics of small circuit elements may be determined directly in terms of voltage and current. This fact makes possible the establishment of a standard electrodynamic ammeter for the very-high-frequency range.

Such an electrodynamic ammeter design, employing a short-circuited ring coupled to a coaxial transmission line, has been the subject of a theoretical and experimental study by Max Solow of the National Bureau of Standards. His work extends a previous study by Turner and Michel at Yale University. Basically the method depends on a torque measurement on a conducting ring immersed in a field which does not change with frequency. This technique provides an absolute, broad-band measurement of high-frequency current, but several factors are critical in any actual electrodynamic ammeter design.

For minimum distributed capacitance and uniform current, the short-circuited ring must be only a single turn, and the ring diameter must be small with respect to wavelength. For accurate inductance calculations, the ring conductor should have a small cross section but resistance then limits the current. A ring of Number 20 copper wire, one centimeter in diameter, is a practical size. When the ring current is small the torque is also small, and the ring must be suspended on a delicate quartz fiber for accurate torque measurements. The coaxial line, acting as the primary current-carrying element for the electrodynamic ammeter, has several advantages over other forms of conductors. Its electromagnetic field can be calculated in a straightforward manner and the line may be readily modified for calibration work with different types of radio-frequency ammeters.

Calibration of the electrodynamic ammeter may be accomplished directly and absolutely. A section of the coaxial transmission line, one wavelength long at 300 megacycles, is arranged with short-circuited ends to form a resonant cavity and the torque ring is placed midway along the section. A known value of 300-megacycle power is fed into an input loop at one end of the cavity. Under these conditions, the torque ring will be at a current maximum and a voltage minimum and the measured torque on the ring will be due almost entirely to the magnetic component of the cavity field. The measurement is then repeated at 150 megacycles, where the current and voltage relations are reversed, and the torque is due only to the electric component. One further measurement is needed for absolute calibration of the ammeter. The cavity resonance frequency is measured at both 300 and 150 megacycles with and without the torque ring in place. The resulting changes in frequency are then a measure of the field discontinuity introduced by the presence of the ring. After the torque and discontinuity measurements are completed, the instrument will be ready for use as a standard to calibrate other ammeters at very high frequencies.



An end-on view of the very-high-frequency electrodynamic ammeter, showing a thermocouple element in place for calibration. The inner conductor of the coaxial line is supported by polystyrene foam which has a negligible effect on the electromagnetic field. In use, copper plates cover the ends to isolate the ammeter from external fields

ASEE Names Award Recipients and Elects New Officers

The three top awards in American engineering education were given recently by the American Society for Engineering Education to Professor F. B. Seely, University of Illinois; Professor Rolf Eliassen, Massachusetts Institute of Technology; and Dean H. P. Hammond, Pennsylvania State College.

Four other engineering educators were honored by election as new officers of the society. They are: president, Dean F. M. Dawson, State University of Iowa; vice-presidents, Dr. G. A. Rosselot, Georgia Institute of Technology, and Professor L. E. Grinter, Illinois Institute of Technology; and treasurer, C. L. Skelley, MacMillan Company.

For his work in establishing the society's Committee on International Relations, Dean H. O. Croft of the University of Missouri received the French Medal of Academy Palm.

Professor Seely, recipient of the ASEE Lamme Medal for distinguished contributions to teaching and engineering administration, is chairman of the Department of Theoretical and Applied Mechanics at the University of Illinois. Professor Eliason, recipient of the $1,000 George Westinghouse Award for outstanding teaching in engineering, is director of studies in sanitary engineering in the Department of Civil and Sanitary Engineering at Massachusetts Institute of Technology. Dean Hammond, who received the first $500 James H. McGraw, Sr., Award for distinguished contributions to technical institute education, is dean of the School of Engineering at Pennsylvania State College. Dean Croft, recipient of the French Academy award, is dean of the College of Engineering at the University of Missouri.

Dean Dawson, new president of the

society, is dean of the College of Engineering at the State University of Iowa. Dr. Grinter, newly elected vice-president, is research professor of civil engineering and mechanics at the Illinois Institute of Technology. Dr. Rosselot, also a newly elected vice-president, is director of the Engineering Experiment Station at the Georgia Institute of Technology. Mr. Skelley, the new treasurer, is manager of the technical book department of the MacMillan Company.

Sorensen Fellowship Established for Graduate EE Students

The former students of Professor Royal W. Sorensen of the California Institute of Technology have set up a fellowship at graduate level, which is to be known as the Royal W. Sorensen Fellowship in Electrical Engineering.

The new fellowship is to be awarded each year to a graduate student in electrical engineering, to be selected by the Division of Engineering at California Institute of Technology. The fellowship carries with it a stipend of $900 for the year. An applicant for the fellowship is also entitled to apply to California Institute of Technology for a tuition rebate, which may be granted if needed.

Dr. Calvert Elected President of Technical Societies Council

Dr. Robert Calvert, a former research laboratory director, has been elected president of the Technical Societies Council of New York, Inc. The Council is an affiliation of the New York sections of 17 of the leading engineering and chemical societies representing more than 25,000 members.

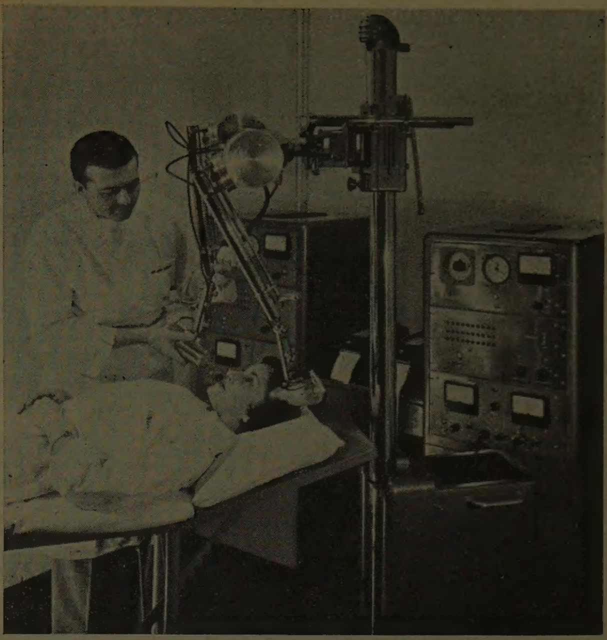
Among other officers elected to the Council at its fourth annual meeting are: vice-president, P. T. Onderdonk of Consolidated Edison Company; secretary, R. F. Warren III of *Chemical Engineering;*; and treasurer, T. R. Leadbeater, Ford Instrument Company.

Atomic Robot Speeds Diagnosis of Brain Tumors

A new atomic robot called the Isotron, designed by the Nuclear Instrument and Chemical Corporation of Chicago, Ill., is now being used to locate tumor tissue accurately. Instead of the skull incisions formerly necessary in many cases, the procedure consists simply of giving the patient an injection of a radioactive isotope. This radioactive tracer accumulates in the tumor tissue and proceeds to send out radiations which are received by the two Geiger counter arms of the Isotron. Within a few minutes the existence and location of any possible tumor tissue can be determined definitely.

The versatility needed for this type of work required that the instrument incorporate two separate channels with scaling circuits, count rate circuits, automatic timing controls, and a circuit which calculated the amount of unbalance between the two main channels. Six different chassis were built into two consoles, and both low- and high-speed recorders were provided.

The drug used to carry the radioactive isotope is diiodofluorescein. This drug was specially formulated for the purpose by Abbott Laboratories, North Chicago, Ill., and contains controlled amounts of radioactive iodine. Upon entering the blood stream, the formulation gradually concentrates in tumor tissue and the Geiger counters of the Isotron detect it easily and precisely. If no tumor is present, a different reaction is obtained than if the suspected tumor is there.



Isotron in position to examine a patient for brain tumor tissue

Radio Noise Meter Standardized. Proposed American Standard specifications for a radio noise meter, 0.015 to 25 megacycles, have been published for a year's trial by the American Standards Association. The standard contains specifications for an instrument intended for general use in factories and in the field. The proposed specifications for the radio noise meter (*C63.2*) may be obtained from American Standards Association, 70 East 45th Street, New York 17, N. Y., or from the National Electrical Manufacturers Association, 155 East 44th Street, New York 17, N. Y. The price is 65 cents per copy.

Meeting of Engineering Society Secretaries. The 14th Annual Conference of the Council of Engineering Society Secretaries was held at the Engineers Club, New York, N. Y., on June 23 and 24, 1950. Eighteen national societies, two state societies, and five local clubs were represented by the 34 secretaries who were present. Officers for the year 1950–51 are: O. L. Angevine, president; W. M. Carey, vice-president; Ernest Hartford, secretary; and F. G. Horton, treasurer. Directors for 1950–51 are: K. G. Treschow, H. S. Harris, E. H. Robie, and C. S. Pearce.

New Hawaiian Broadcast Station. The Hawaiian Islands newest broadcast station, *KIKI*—Honolulu, is scheduled to go on the air September 1, 1950. The new station will be equipped with a General Electric 250-watt transmitter. Station *KIKI*, which takes its call letters from nearby Waikiki, will be located in downtown Honolulu and will operate on 860 kc. It will employ a 285-foot tower to cover the Island of Oahu and adjacent islands.

Sturrock President of IES. Walter Sturrock, vice-president of the Illuminating Engineering Society since 1948, has been elected the 46th president of the society. He will assume his new office on October 1, 1950, the beginning of the society's fiscal year. Mr. Sturrock is head of the engineering publications section of the General Electric Company's Lamp Department at Nela Park, Cleveland, Ohio.

TV Studio on Wheels for Mexico. Mexico's first television station, Station *XHTV* in Mexico City, has been equipped with a television "studio on wheels" by the Radio Corporation of America, Camden, N. J. The new television station, for which the mobile unit is the final item of equipment, will be North America's first over-the-border link to facilitate an eventual international exchange of television programs.

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

FREQUENCY MODULATION. By K. R. Sturley. Chemical Publishing Company, Brooklyn, N. Y., 1950. 98 pages, diagrams, charts, tables, $8^3/_4$ by $5^1/_2$ inches, cloth, $4.75. This monograph presents a brief review of the theoretical aspects of frequency-modulated radio waves and a concise discussion of the basic problems encountered in the design of frequency-modulation receivers. A bibliography, many diagrams, and a chart showing a typical frequency-modulation receiver circuit are included.

FRICTIONAL PHENOMENA. By A. Gemant. Chemical Publishing Company, Brooklyn, N. Y., 1950. 497 pages, diagrams, charts, tables, $8^3/_4$ by $5^1/_2$ inches, cloth, $12. Based largely on a series of articles published in the *Journal of Applied Physics* during the years 1941–43, this monograph deals with both the physical basis and the engineering applications of friction. It is concerned with friction in gases, liquids, colloids, plastics, and metals. Important topics dealt with include the following: engineering applications of friction; sound-absorbing materials; viscometry; electrical insulating liquids in high-voltage cables; plastic flow of solids; reduction of vibrations. Literature references have been brought up to date.

BEST'S SAFETY DIRECTORY 1950–1951, Third edition. Alfred M. Best Company, 75 Fulton Street, New York, N. Y.; Chicago, Ill.; Cincinnati, Ohio; Boston, Mass.; Dallas, Tex.; Atlanta, Ga.; Chattanooga, Tenn.; Los Angeles, Calif.; 1950. 511 pages, illustrations, diagrams, $11^1/_4$ by $8^1/_4$ inches, fabrikoid, $5. This directory contains classified listings of manufacturers of safety products and devices for every field of industry. Safety instructions and condensed classifications of equipment types precede the several sections, and precise definitions are given for the specific items listed in the directory. Among the changes in the new edition is the inclusion of a section on burglary protective equipment and alarm systems.

BRANS' VADE-MECUM 1950, Eighth International Edition. P. H. Brans, Antwerp, Belgium, distributed by Editors and Engineers, Ltd., 1300 Kenwood Road, Santa Barbara, Calif., 1950. 508 pages, diagrams, tables, $11^1/_2$ by 8 inches, paper, $3. This comprehensive annual guide provides a general index of radio tube types, tables of tube characteristics, and now includes the tables of base connections formerly issued in separate form. As usual, new types have been added, including sections for crystal diodes and crystal triodes. In keeping with the worldwide character of the contained information, the introduction, table of contents, directions for using the manual, and the list of abbreviations and symbols used are repeated in eight languages. Russian tubes are listed separately at the end of the respective sections.

COLD CATHODE FLUORESCENT LIGHTING. By H. A. Miller. Chemical Publishing Company, Brooklyn, N. Y., 1949. 130 pages, illustrations, diagrams, tables, charts, $8^3/_4$ by $5^1/_2$ inches, cloth, $3.75. Written in a popular style, this book is of interest to the electrical and illuminating engineer, as well as to users and potential users of fluorescent lighting. It describes the principles, manufacture, operation, and installation of cold-cathode fluorescent lighting and considers its application in home, theater, office, and especially in commercial displays.

DÉTERMINATION D'UN ÉTAT PLAN DES CONTRAINTES A L'AIDE D'UN EXTENSIOMÉTRE A RÉSISTANCE ÉLECTRIQUE A TROIS DIRECTIONS (Rosette). ABAQUES PRATIQUES D'EMPLOI. (Bulletins des Services Techniques Number 112). By F. T. Salles, preface by M. P. Gross. En Vente au Service de Documentation et d'Information Technique de l'Aéronautique, Magasin C.T.O.: 2, Rue de la Porte-d'Issy, Paris (15°), France, 1949. 41 pages, diagrams, charts, tables, $10^1/_2$ by 7 inches, paper, 350 frs. The theory of strain rosettes is established using the "circle of deformations," and formulas are developed giving the strains and their directions as a function of three deformations. Tables are provided to reduce the amount of work required and nomograms are provided for various gauge settings. The treatment applies to the use of electric resistance strain gauges.

DIRECT CURRENT MOTOR MANUAL. By H. S. Dusenbery. The Macmillan Company, New York, N. Y., 1950. 275 pages, illustrations, diagrams, charts, tables, $8^1/_2$ by $5^1/_2$ inches, cloth, $3.50. Written for the practical man, this book provides the information and instruction that a d-c motor user and operator needs to know, from basic theory to all details of the construction, operation, and servicing of each part of the motor. Extensive trouble charts show the correction of every conceivable motor trouble, and detailed maintenance charts provide aid toward trouble prevention. Modern electronic methods of control are discussed. The National Electric Code rules and requirements are included, as well as complete reference tables and a glossary of technical terms.

ELECTRICAL METERMEN'S HANDBOOK. Edison Electric Institute, 420 Lexington Avenue, New York, N. Y. Sixth edition, revised and edited, 1950. 615 pages, illustrations, diagrams, charts, tables, $8^3/_4$ by $5^1/_4$ inches, fabrikoid, $4.90. This handbook covers the basic principles of metering both energy and power, and contains descriptions of all types of meters in current use. In this sixth edition, there are two new sections dealing with principles of demand meters and with problems connected with special metering. The appendix contains information from the 1923 edition which shows the essential data required in the maintenance of older meters still in general use. Much new material is added throughout the book to show the most modern equipment, methods, and engineering practices.

Library Services

ENGINEERING Societies Library books may be borrowed by mail by AIEE members for a small handling charge. The library also prepares bibliographies, maintains search and photostat services, and can provide microfilm copies of any item in its collection. Address inquiries to Ralph H. Phelps, Director, Engineering Societies Library, 29 West 39th St., New York 18, N. Y.

ELECTRONICS, PRINCIPLES AND APPLICATIONS. By R. R. Wright. Ronald Press Company, New York, N. Y., 1950. 387 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $5.50. Written primarily for nonelectrical engineering students, this book explains the basic principles of electronics and provides an understanding of how these principles can be applied to control or facilitate various industrial processes. Topics are presented from a qualitative rather than quantitative point of view. One chapter briefly reviews d-c and a-c circuits, and more than half of the book deals with basic applications of electron tubes. Problems and a bibliography are placed at the end of each chapter.

ENGINEERING ECONOMIC ANALYSIS. By C. E. Bullinger. Second edition. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England; 1950. 397 pages, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $4. The four main divisions of this text deal respectively with the following aspects of an engineering project: the economy analysis, concerned with the problem of yield on the investment; the financial analysis, dealing with the provision of funds; the analysis of intangibles, evaluating the factors in which human judgment is involved; and special methods and applications, as in the consideration of the economic characteristics of power-generating and power-using equipment. Tables and formulas for the necessary calculations are provided in appendixes.

EXPERIMENTAL DESIGNS. By W. G. Cochran and G. M. Cox. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1950. 454 pages, tables, $9^1/_4$ by 6 inches, cloth, $5.75. Experiments, to produce dependable results, must take into account all possible variables which might introduce uncertainty. This guide describes in detail the most useful statistical designs which have been developed for this purpose, with accompanying plans and an account of the experimental situations for which each design is most suitable. A brief review of the basic theory of the analysis of variance is included, with illustrative worked examples.

FORTLEITUNG ELEKTRISCHER ENERGIE LÄNGS LEITUNGEN IN STARKSTROM- UND FERNMELDETECHNIK. By W. zur Megede. Springer-Verlag, Berlin, Göttingen, Heidelberg, Germany, 1950. 163 pages, diagrams, charts, tables, 9 by 6 inches, paper, 13.50 DM. Discusses the transmission of electric energy along wires in high-voltage and long-distance communication technique. Both theoretical and practical aspects are considered. In the early chapters, the principles of wire transmission are presented. The subsequent chapters deal with particular applications and the characteristics of typical problems. A number of theoretical and mathematical aids are included in an appendix.

(The) MARKET FOR COLLEGE GRADUATES. By S. E. Harris. Harvard University Press, Cambridge, Mass., 1949. 207 pages, diagrams, charts, tables, $8^1/_2$ by $5^1/_2$ inches, cloth, $4. Proceeding on the premise that the number of college graduates is steadily outstripping the number of jobs available within the chosen professions, the author presents first a general survey of the problem and then a detailed analysis and documentation. The related aspects of education and income are discussed, and certain solutions are proposed for relieving the general situation.

(The) MEANING OF RELATIVITY. By A. Einstein. Third edition. Princeton University Press, Princeton, N. J., 1950. 150 pages, diagrams, charts, 8 by $5^1/$ inches, linen, $2.50. This book contains the author' explanation of both the special and the general theorie of relativity, including, in Appendix I, significant advances made since the original publication of the theory Appendix II, added to this third edition, presents the new "generalized theory of gravitation," which attempt to interrelate all known physical phenomena.

MÉMENTO D'ÉLECTROTECHNIQUE, Volume II Machines et Appareils Électriques. MÉMENTO D'ÉLECTROTECHNIQUE, Volume III. Réseau de Distribution d'Énergie Électrique. By A. Curchod Second edition. Revised by L. Vellard. Dunod, Éditeur, 1950. Diagrams, charts, tables, $8^3/_4$ by $5^1/$ inches, fabrikoid. Volume II, 564 pp., 2,100 frs.; Volume III, 727 pages, 2,650 frs. Volumes II and III of this series cover, respectively, the practical applications of electricity and magnetism and the productio and distribution of electric energy. Volume II deal with the general subject of electromagnetic machine and equipment: motors, generators, transformers, rotary convertors, rectifiers, high-voltage generators, cyclotrons, and so forth, covering both a-c and d-c operation Volume III describes the transmission and distributio of electric energy both overhead and underground; covers in detail the equipment and operation of steam- and hydroelectric stations, transformer groups, and substations; and discusses hydraulic energy sources.

OVERHEAD LINE PRACTICE. By J. McCombe. Macdonald and Company (Publishers) Ltd., 43 Ludgate Hill, London, E. C. 4, England, 1949. 269 pages, illustrations, diagrams, charts, tables, $8^3/_4$ by $5^1/_2$ inches, cloth, 25s. Of interest to foremen and linesmen a well as to engineers, this book is concerned with the details of layout, design, and erection of overhead power lines. It includes an elementary chapter o surveying. Special emphasis is laid on the importanc of proper connections of ample area on systems with high short-circuit current values.

PAMPHLETS • • • • •

The following recently issued pamphlets may be o interest to readers of "Electrical Engineering." Al inquiries should be addressed to the issuers.

Speaking Can Be Easy. A practical pocket-size manual written by experienced engineering speakers especially for the engineer. Includes a section on the conduct of meeting and conferences. Available at 50 cent per copy from the Engineers' Council fo Professional Development, 29 West 39th Street, New York 18, N. Y.

Solders and Soldering. Describes in detail types of solder and soldering procedures. Instructions are given for the proper use o each type of solder for joints of the require strength. 12 pages. Available from the Superintendent of Documents, Governmen Printing Office, Washington 25, D. C., a 15 cents a copy.

Recommended Practice of Library Lighting. Prepared as an aid to architects builders, consultants, and lighting specialist concerned with illumination in publi buildings and institutions. 16 pages Available at 50 cents per copy with quantit prices upon request from the Publication Office, Illuminating Engineering Society 51 Madison Avenue, New York 10, N. Y.

Development of the National Bureau o Standards Casting Resin. Describes tes procedures and results obtained with special casting resin developed to improv the stability and ruggedness of electroni circuits. 10 pages. Illustrated. Availabl from the Superintendent of Documents Government Printing Office, Washingto 25, D. C., at 10 cents a copy.